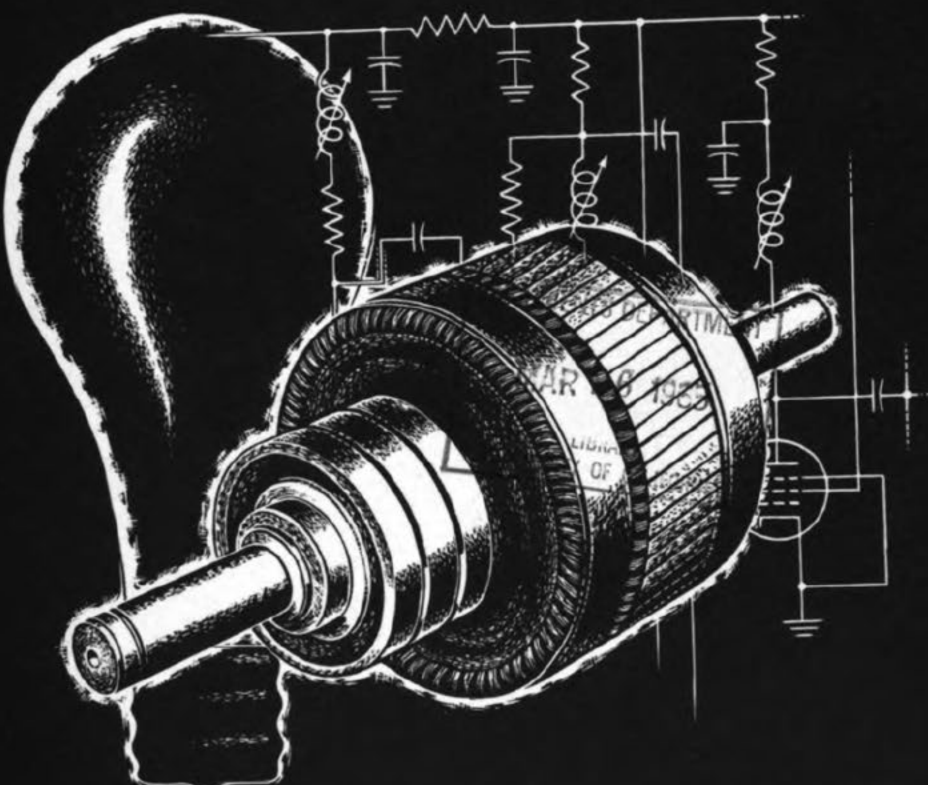

ELECTRICIAN'S MATE 1 & C

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10547-A

PREFACE

This training course is written to aid enlisted men in the U.S. Navy and Navy Reserve in preparing for advancement to the rate of Electrician's Mate 1 and Chief Electrician's Mate.

The subjects with which the EM2 or EM1 must be familiar before he can qualify for advancement to Electrician's Mate 1 or C are outlined in the Manual of Qualifications for Advancement in Rating. This training course contains information on each examination, and, insofar as practicable, information on each practical factor. Because examinations for advancement in rating are based on these qualifications, interested personnel should refer to them for guidance (the LATEST qualifications should always be consulted).

The Electrician's Mate 1 & C training course was prepared by the U.S. Navy Training Publications Center, Washington, D.C., which is a field activity of the Bureau of Naval Personnel. Technical assistance was provided by the Bureau of Naval Personnel, the Bureau of Ships, and the Service School Command, U.S. Navy Training Center, Great Lakes, Illinois.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

READING LIST

NAVY TRAINING COURSES

Basic Electricity, NavPers 10086-A

Basic Handtools (metal working skills only), NavPers 10085-A

Blueprint Reading and Sketching (chapters 5 & 6), NavPers 10077-B

Introduction to Electronics (chapters 1 thru 6), NavPers 10084

Standard First Aid, NavPers 10081-A

Mathematics Vol. 1, NavPers10069-B

Mathematics Vol. 2, NavPers 10071-A

OTHER PUBLICATIONS

Bureau of Ships Technical Manual, chapters 9450; 9600; 9610; 9620; 9630; 9640; 9660; 9681; and 9688.

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Educational Services' Officer.* The following is a partial list of those courses applicable to your rate:

D290	Physics I
C781	Fundamentals of Electricity
C858	The Slide Rule
D435	Plane Trigonometry

*"Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI course, services, and materials if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified on the active duty order."

CHAPTER 1

ADVANCEMENT

This training course is designed to help you in preparing for advancement to Electrician's Mate First Class or Chief. The professional (technical) qualifications for advancement to EM1 and EMC as listed in Group 7 of the Manual of Qualifications for Advancement in Rating, NavPers 18068-A, (with change 1) were used as a guide in preparing the course.

This chapter discusses the enlisted rating structure, and also includes material relating to the Electrician's Mate rating. Suggestions on how to qualify and prepare for advancement are given. The chapter also includes material concerning the increased responsibilities regarding leadership, supervision, and training, that will be yours upon advancement.

Chapters 2 and 3 of this training course explain the practical factors of maintaining, testing, and repairing a-c and d-c windings associated with generators and motors.

The fourth chapter contains information concerning requirements for closely regulated shipboard power systems. Types I, II, and III power, and the voltage and frequency regulating equipments associated with each type, are presented.

Chapter 5 deals with automatic degaussing installations using the type GM-1A as a representative system. The chapter also includes a brief discussion of degaussing systems for mine warfare ships.

Chapter 6 discusses the broad aspects of engineering casualty control concerning electric propulsion and electric plants aboard ship.

The seventh chapter covers shipboard electrical maintenance and repair procedures. Repairs and alterations are defined. The Standard Navy Maintenance Management System with its application to electrical equipment is discussed. The chapter also includes material concerning the preparation and processing of work requests, and repair procedures for repair activities afloat and ashore.

Chapter 8 describes the various types of inspections as they apply to the engineering department. Following that description, full power and economy trials are discussed.

Chapter 9 contains material relating to electrical safety precautions, and the duties and responsibilities of the senior Electrician's Mate concerning safety.

The remainder of this first chapter gives information that will help you in working for advancement in rating. Study this chapter carefully before beginning intensive study of chapter 2 and the remainder of this training course.

THE ENLISTED RATING STRUCTURE

The present enlisted rating structure, established in 1957, includes three types of ratings: general ratings, service ratings, and emergency ratings.

GENERAL RATINGS are designed to provide paths of advancement and career development. A general rating identifies a broad occupational field of related duties and functions requiring similar aptitudes and qualifications. General ratings provide the primary means used to identify billet requirements and personnel qualifications. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

Subdivisions of certain general ratings are identified as SERVICE RATINGS. These service ratings identify areas of specialization within the scope of a general rating. Service ratings are established in those general ratings in which specialization is essential for efficient utilization of personnel. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

EMERGENCY RATINGS identify essentially civilian occupations. Emergency ratings are not identified as ratings in the peacetime Navy, but their identification is required in time of war.

THE EM RATING

The EM rating is a general rating only. Electrician's Mates are included in the personnel allowance for practically all types of Navy ships including repair ships and tenders.

As an EM1 you may be assigned to almost any type of ship, and may be required to fill the senior Electrician's Mate billet on ships the size of a destroyer and smaller. Chief Electrician's Mates are usually assigned to ships the size of destroyers and larger.

Shore billets for Chief and First Class Electrician's Mates include recruiting duty, and instructor duty at class A, B, and C schools, recruit training commands, and Naval Reserve training centers. Other billets for Chief Electrician's Mates include the U. S. Navy Examining Center, Great Lakes, Ill., and the Navy Training Publication Center, Washington, D. C.

DUTIES

Electrician's Mates stand watch on generators, switchboards, and control equipment; operate electrical equipment; maintain and repair power and lighting circuits, electrical fixtures, motors, generators, distribution switchboards, and other electrical equipment; and repair and rebuild electrical equipment in electrical shops. The specific jobs and procedures for carrying out these duties are continually changing, due to the development of new and improved electrical equipments and systems.

New equipments either in operation at present, under evaluation, or being developed, include electric governors for ship's service generators, and static type line voltage regulators, motor controllers, and inverters. Printed circuit motors are also being investigated.

In addition, to reduce the number of ship's service generators on large ships, higher voltage distribution systems are being investigated. A 2300-volt system has been developed by the Bureau of Ships, and 4160-volt systems are being studied for future large ships.

ADVANCEMENT IN RATING

By this time, you are probably well aware of the personal advantages of advancement in rating—higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. By this time, also, you have probably discovered that one of the most enduring rewards of advancement is the training you acquire in the process of preparing for advancement.

The Navy also profits by your advancement. Highly trained personnel are essential to the functioning of the Navy. By each advancement in rating, you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And second, you become more valuable as a person who can supervise, lead, and train others and thus make far-reaching contributions to the entire Navy.

Since you are studying for advancement to PO1 or CPO, you are probably already familiar with the requirements and procedures for advancing in rating. However, you may find it helpful to read the following sections. The Navy does not stand still. Things change all the time, and it is possible that some of the requirements have changed since the last time you were going up for advancement in rating. Furthermore, you will be responsible for training others for advancement, and so will need to know the requirements in some detail.

HOW TO QUALIFY FOR ADVANCEMENT

To qualify for advancement in rating, a person must:

1. Have a certain amount of time in grade.
2. Complete the required military and professional training courses.
3. Demonstrate the ability to perform all the PRACTICAL requirements for advancement by completing applicable portions of the Record of Practical Factors, NavPers 760.
4. Be recommended by his commanding officer.
5. Demonstrate his KNOWLEDGE by passing a written examination on (a) military requirements, and (b) professional qualifications.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives an overall view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	† E6 to E7	† E7 to E8	† E8 to E9
SERVICE	4 mos. service— or completion of recruit training.	6 mos. as E-2.	6 mos. as E-3.	12 mos. as E-4.	24 mos. as E-5.	36 mos. as E-6.	48 mos. as E-7. 8 of 11 years total service must be enlisted. Must be permanent appointment.	24 mos. as E-8. 10 of 13 years total service must be enlisted.
SCHOOL	Recruit Training.		Class A for PR3, DT3, PT3, AME 3, HM 3			Class B for AGCA, MUCA, MNCA.		
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS	Locally prepared tests.		Navy-wide examinations required for all PO advancements.				Navy-wide, selection board, and physical.	
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).					Correspondence courses and recommended reading. See NavPers 10052 (current edition).	
AUTHORIZATION	Commanding Officer		U.S. Naval Examining Center			Bureau of Naval Personnel		
	TARS attached to the air program are advanced to fill vacancies and must be approved by CNARESTRA.							

* All advancements require commanding officer's recommendation.
† 2 years obligated service required.

Figure 1-1.—Active duty advancement requirements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS *	FOR THESE DRILLS PER YEAR	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	48	6 mos.	6 mos.	15 mos.	18 mos.	24 mos.	36 mos.	48 mos.	24 mos.
	24	9 mos.	9 mos.	15 mos.	18 mos.	24 mos.	36 mos.	48 mos.	24 mos.
	NON-DRILLING	12 mos.	24 mos.	24 mos.	36 mos.	48 mos.	48 mos.		
DRILLS ATTENDED IN GRADE †	48	18	18	45	54	72	108	144	72
	24	16	16	27	32	42	64	85	32
TOTAL TRAINING DUTY IN GRADE †	48	14 days	14 days	14 days	14 days	28 days	42 days	56 days	28 days
	24	14 days	14 days	14 days	14 days	28 days	42 days	56 days	28 days
	NON-DRILLING	None	None	14 days	14 days	28 days	28 days		
PERFORMANCE TESTS				Specified ratings must complete applicable performance tests before taking examination.					
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 760, must be completed for all advancements.							
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.							
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.						Standard EXAM, Selection Board, and Physical.	
AUTHORIZATION		District commandant or CNARESTRA					Bureau of Naval Personnel		

* Recommendation by commanding officer required for all advancements.
† Active duty periods may be substituted for drills and training duty.

Figure 1-2.—Inactive duty advancement requirements.

Remember that the requirements for advancement can change. Check with your division officer or training officer to be sure that you know the most recent requirements.

When you are training lower rated personnel, it is a good idea to point out that advancement in rating is not automatic. Meeting all the requirements makes a person ELIGIBLE for advancement, but it does not guarantee his advancement. Such factors as the score made on the written examination, length of time in service, performance marks, and the quotas for the rating enter into the final determination of who will actually be advanced.

HOW TO PREPARE FOR ADVANCEMENT

Preparations for advancement in rating include studying the qualifications, working on the practical factors, studying the required Navy Training Courses, and studying any other material that may be specified for the rate and rating. To prepare for advancement yourself or to help others prepare for advancement, you will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, NavPers 760, (3) a NavPers publication called Training Publications for Advancement in Rating, NavPers 10052, and (4) Navy Training Courses. The following sections describe these materials and give some information on how to use them to best advantage.

The Quals Manual

The Manual of Qualifications for Advancement in Rating, NavPers 18068-A (with changes), gives the minimum requirements for advancement to each rate within each rating. This manual is usually called the "Quals Manual," and the qualifications themselves are often called "quals." The qualifications are of two general types: (1) military requirements, and (2) professional or technical qualifications. Military requirements apply to all ratings rather than to any one rating alone. Professional qualifications are technical or professional requirements that are directly related to the work of each rating.

Both the military requirements and the professional qualifications are divided into subject matter groups. Then, within each subject matter group, they are divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS.

The professional qualifications for advancement in your rating covered in this training course were current at the time this training course was printed. However, the Quals Manual is changed more frequently than Navy Training Courses are revised. By the time you are studying this training course, therefore, the quals for your rating may have been changed. Never trust any set of quals until you have checked it against an UP-TO-DATE copy in the Quals Manual.

In training others for advancement in rating, emphasize these three points about the quals:

1. The quals are the MINIMUM requirements for advancement to each rate within the rating. Personnel who study MORE than the required minimum will have a great advantage when they take the written examinations for advancement.

2. Each qual has a designated rate level—chief, first class, second class, or third class. You are responsible for meeting all quals specified for the rate level to which you are seeking advancement AND all quals specified for lower rate levels.

3. The written examinations for advancement in rating will contain questions relating to the practical factors AND to the knowledge factors of BOTH the military requirements and the professional qualifications.

Record of Practical Factors

A special form known as the RECORD OF PRACTICAL FACTORS, NavPers 760, is used to record the satisfactory performance of the practical factors. This form, which is available for all ratings, lists all the military and all the professional practical factors. Whenever a person demonstrates his ability to perform a practical factor, appropriate entries must be made in the DATE and INITIALS columns. As a PO1 or CPO, you will often be required to check the practical factor performance of lower rated personnel and to report the results to your supervising officer.

As changes are made periodically to the Quals Manual, new forms of NavPers 760 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement. Keep this in mind when you are training and supervising other personnel. If a person demonstrates proficiency

in some skill which is not listed in the quals but which is within the general scope of the rating, report this fact to the supervising officer so that an appropriate entry can be made in the Record of Practical Factors.

When you are transferred, the Record of Practical Factors should be forwarded with your service record to your next duty station. It is a good idea to check and be sure that this form is actually inserted in your service record before you are transferred. If the form is not in your record, you may be required to start all over again and requalify in practical factors that have already been checked off. You should also take some responsibility for helping lower rated personnel keep track of their practical factor records when they are transferred.

NavPers 10052

Training Publications for Advancement in Rating, NavPers 10052 (revised) is a very important publication for anyone preparing for advancement in rating. This publication lists required and recommended Navy Training Courses and other reference material to be used by personnel working for advancement in rating. NavPers 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the NavPers number. When using the publication, be SURE you have the most recent edition.

The required and recommended references are listed by rate level in NavPers 10052. It is important to remember that you are responsible for all references at lower rate levels, as well as those listed for the rate to which you are seeking advancement.

Navy Training Courses that are marked with an asterisk (*) in NavPers 10052 are MANDATORY at the indicated rate levels. A mandatory training course may be completed by (1) passing the appropriate Enlisted Correspondence Course that is based on the mandatory training course; (2) passing locally prepared tests based on the information given in the mandatory training course; or (3) in some cases, successfully completing an appropriate Navy school.

When training personnel for advancement in rating, do not overlook the section of NavPers 10052 which lists the required and recommended references relating to the military requirements for advancement. Personnel of all ratings must complete the mandatory military requirements training course for the appropriate rate level before they can be eligible to advance in rating. Also, make sure that personnel working for advancement study the references which are listed as recommended but not mandatory in NavPers 10052. It is important to remember that ALL references listed in NavPers 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Navy Training Courses

There are two general types of Navy Training Courses. RATING COURSES (such as this one) are prepared for most enlisted ratings. A rating training course gives information that is directly related to the professional qualifications of ONE rating. SUBJECT MATTER COURSES or BASIC COURSES give information that applies to more than one rating.

Navy Training Courses are revised from time to time to bring them up to date. The revision of a Navy Training Course is identified by a letter following the NavPers number. You can tell whether a Navy Training Course is the latest edition by checking the NavPers number (and the letter following the number) in the most recent edition of List of Training Manuals and Correspondence Courses, NavPers 10061.

Navy Training Courses are designed for the special purpose of helping naval personnel prepare for advancement in rating. By this time, you have probably developed your own way of studying these courses. Some of the personnel you train, however, may need guidance in the use of Navy Training Courses. Although there is no single "best" way to study a training course, the following suggestions have proved useful for many people.

1. Study the military requirements and the professional qualifications for your rating before you study the training course, and refer to the quals frequently as you study. Remember, you are studying the training course primarily to meet these quals.

2. Before you begin to study any part of the training course intensively, get acquainted with the entire book. Read the preface and the table of contents. Check through the index. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

3. Look at the training course in more detail, to see how it is organized. Look at the

table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book.

4. When you have a general idea of what is in the training course and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

5. In studying each unit, write down questions as they occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

6. As you study, relate the information in the training course to the knowledge you already have. When you read about a process, a skill, or a situation, ask yourself some questions. Does this information tie in with past experience? Or is this something new and different? How does this information relate to the qualifications for advancement in rating?

7. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Without looking at the training course, write down the main ideas you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

8. Use Enlisted Correspondence Courses whenever you can. The correspondence courses are based on Navy Training Courses or other appropriate texts. As mentioned before, completion of a mandatory Navy Training Course can be accomplished by passing an Enlisted Correspondence Course based on the training course. You will probably find it helpful to take other correspondence courses, as well as those based on mandatory training courses. Taking a correspondence course helps you to master the information given in the training course, and also gives you an idea of how much you have learned.

INCREASED RESPONSIBILITIES

When you assumed the duties of a PO3, you began to accept a certain amount of responsibility for the work of others. With each advancement in rating, you accept an increasing responsibility in military matters and in matters relating to the professional work of your rating. When you advance to PO1 or CPO, you will find a noticeable increase in your responsibilities for leadership, supervision, training, working with others, and keeping up with new developments.

As your responsibilities increase, your ability to communicate clearly and effectively must also increase. The simplest and most direct means of communication is a common language. The basic requirement for effective communication is therefore a knowledge of your own language. Use correct language in speaking and in writing. Remember that the basic purpose of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

Leadership and Supervision

As a PO1 or CPO, you will be regarded as a leader and supervisor. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed, practical, on-the-job language that can be understood and followed by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their jobs correctly. At the same time, you must be able to explain to officers any important problems or needs of enlisted personnel. In all military and professional matters, your responsibilities will extend both upward and downward.

Along with your increased responsibilities, you will also have increased authority. Officers and petty officers have POSITIONAL authority—that is, their authority over others lies in their positions. If your CO is relieved, for example, he no longer has the degree of authority over you that he had while he was your CO, although he still retains the military authority that all seniors have over subordinates. As a PO1, you will have some degree of positional authority; as a CPO, you will have even more. When exercising your authority, remember that it is positional—it is the rate you have, rather then the person you are, that gives you this authority.

Training

As a PO1 or CPO, you will have regular and continuing responsibilities for training others.

Even if you are lucky enough to have a group of subordinates who are all highly skilled and well trained, you will still find that training is necessary. For example, you will always be responsible for training lower rated personnel for advancement in rating. Also, some of your best workers may be transferred; and inexperienced or poorly trained personnel may be assigned to you. Or a particular job may call for skills that none of your personnel have. These and similar problems require that you be a training specialist—one who can conduct formal and informal training programs to qualify personnel for advancement in rating, and one who can train individuals and groups in the effective execution of assigned tasks.

In using this training course, study the information from two points of view. First, what do you yourself need to learn from it? And second, how would you go about teaching this information to others?

Training goes on all the time. Every time a person does a particular piece of work, some leading is taking place. As a supervisor and as a training expert, one of your biggest jobs is to see that your personnel learn the RIGHT things about each job so that they will not form bad work habits. An error that is repeated a few times is well on its way to becoming a bad habit. You will have to learn the difference between oversupervising and not supervising enough. No one can do his best work with a supervisor constantly supervising. On the other hand, you cannot turn an entire job over to an inexperienced person and expect him to do it correctly without any help or supervision.

In training lower rated personnel, emphasize the importance of learning and using correct terminology. A command of the technical language of your rating enables you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms used in connection with the work of his rating is definitely at a disadvantage when he tries to read official publications relating to his work. He is also at a great disadvantage when he takes the examinations for advancement in rating. To train others in the correct use of technical terms, you will need to be very careful in your own use of words. Use correct terminology and insist that personnel you are supervising use it too.

You will find the Record of Practical Factors, NavPers 760, a useful guide in planning and carrying out training programs. From this record, you can tell which practical factors have been checked off and which ones have not yet been done. Use this information to plan a training program that will fit the needs of the personnel you are training.

On-the-job training is usually controlled through daily and weekly work assignments. When you are working on a tight schedule, you will generally want to assign each person to the part of the job that you know he can do best. In the long run, however, you will gain more by assigning personnel to a variety of jobs so that each person can acquire broad experience. By giving people a chance to do carefully supervised work in areas in which they are relatively inexperienced, you will increase the range of skills of each person and thus improve the flexibility of your working group.

Working With Others

As you advance to PO1 or CPO, you will find that many of your plans and decisions affect a large number of people, some of whom are not even in your own rating. It becomes increasingly important, therefore, for you to understand the duties and the responsibilities of personnel in other ratings. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of other ratings, and plan your own work so that it will fit into the overall mission of the organization.

Keeping Up With New Developments

Practically everything in the Navy—policies, procedures, publications, equipment, systems—is subject to change and development. As a PO1 or CPO, you must keep yourself informed about changes and new developments that affect you or your work in any way.

Some changes will be called directly to your attention, but others you will have to look for. Try to develop a special kind of alertness for new information. When you hear about anything new in the Navy, find out whether there is any way in which it might affect the work of your rating. If so, find out more about it.

SOURCES OF INFORMATION

As a PO1 or CPO, you must have an extensive knowledge of the references to consult for accurate, authoritative, up-to-date information

on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some publications are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, make sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made.

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. A selected list of training films that may be useful to you is given in appendix 1 of this training course. Other films that may be of interest are listed in the United States Navy Film Catalog, NavPers 10000 (revised).

ADVANCEMENT OPPORTUNITIES FOR PETTY OFFICERS

Making chief is not the end of the line as far as advancement is concerned. Proficiency pay, advancement to E-8 and E-9, and advancement to comissioned officer status are among the opportunities that are available to qualified petty officers. These special paths of advancement are open to personnel who have demonstrated outstanding professional ability, the highest order of leadership and military responsibility, and unquestionable moral integrity.

PROFICIENCY PAY

The Career Compensation Act of 1949, as amended, provides for the award of proficiency pay to designated enlisted personnel who possess special proficiency in a military skill. Proficiency pay is given in addition to your regular pay and allowances and any special or incentive pay to which you are entitled. Enlisted personnel in pay grades E-4 through E-9 are eligible for proficiency pay. Proficiency pay is allocated by ratings and NECs, with most awards being given in the ratings and NECs which are designated as critical. The eligibility requirements for proficiency pay are subject to change. In general, however, you must be recommended by your commanding officer, have a certain length of time on continuous active duty, and be career designated.

ADVANCEMENT TO E-8 AND E-9

Chief petty officers may qualify for the advanced grades E-8 and E-9 which are now provided in the enlisted pay structure. These advanced grades provide for substantial increases in pay, together with increased responsibilities and additional prestige. The requirements for advancement to E-8 and E-9 are subject to change, but in general include a certain length of time in grade, a certain length of time in the naval service, a recommendation by the commanding officer, and a sufficiently high mark on the servicewide examination. The final selection for E-8 and E-9 is made by a regularly convened selection board.

Examination Subjects.—The examinations for pay grades E-8 and E-9 are divided into three sections: professional knowledge, supervisory knowledge, and common knowledge. The professional knowledge section is designed to measure, at an advanced level, a candidate's knowledge of his particular rating. Personnel who prepare these questions are guided by the Manual of Qualifications for Advancement in Rating and the related bibliography in Training Publications for Advancement in Rating. Pertinent publications from among those listed in the military requirements section of NavPers 10052 are used as sources of the supervisory knowledge section. The common knowledge section contains questions designed to test the candidate's arithmetical, mechanical, and verbal reasoning capabilities. Questions for this section are drawn from basic mathematics, physics, and vocabulary development texts.

Sources of Information.—In addition to the titles listed above, the following publications, distributed to Navy libraries and Educational Services offices, will assist the candidate for E-8 or E-9 in preparing for the examinations: College Entrance Examinations Study Material (limited distribution); High School Subjects Self Taught Book (Navy-wide distribution); Basic Mathematics (Navy-wide distribution); Mathematics Review (Navy-wide distribution); popular texts on psychology (navy-wide distribution); various USAFI texts (Navy-wide distribution); vocabulary development books (limited distribution).

ADVANCEMENT TO COMMISSIONED OFFICER

The Limited Duty Officer (Temporary) Program provides a path of advancement to commissioned officer status for outstanding petty officers of the Regular Navy. LDOs are limited, in their duty, to the broad technical fields associated with their former rating.

Education, length of service, and maximum age limits are usually specified in the requirements for advancement to LDO. However, these requirements vary according to circumstances, and the program is in a period of transition. If you are interested in advancing to LDO, ask your division officer for the latest requirements that apply to your particular case.

Another path of advancement to commissioned officer status is provided by the Integration Program. Enlisted personnel possessing the required qualifications may be appointed under this program to the grade of ensign in the Line, Supply, or Civil Engineer Corps of the Regular Navy. Education, length of service, and maximum age limits are included in the requirements for eligibility under this program. Eligibility requirements for this program, as well as for the other programs discussed here, are subject to change.

CHAPTER 2

D-C WINDINGS

D-c generators and motors are described in chapters 15 and 16 respectively of Basic Electricity, NavPers 10086-A. Chapter 2 of this training course is a continuation of d-c armature windings and includes a detailed description of the types, troubles, tests, and repairs of these windings.

Accordingly, the drum armature of a d-c machine comprises the armature core, armature winding, and commutator. Also, the armature winding of a d-c generator is similar to that of a d-c motor. The winding consists of a number of identical coils having one or more turns with two or more free ends. Each coil, whether it consists of a single turn or of several turns, is taped as a unit, and the coil sides constitute WINDING ELEMENTS. In other words, the group of wires which constitutes the side of a single coil and which is usually wrapped with tape as a unit is a winding element.

The winding elements are located in slots on the cylindrical surface of the armature core, and the free ends of the elements, or coils, are connected to the commutator. For a given armature winding all elements and their associated connections are identical and the winding is symmetrical.

There are 180 electrical degrees between two adjacent (north and south) poles, and 360 electrical degrees are required for a complete cycle. As a conductor passes from a north to a south to a north pole, it completes one cycle of 360 electrical degrees. The relation between electrical degrees and mechanical degrees is expressed as

$$\text{Mechanical degrees} = \frac{\text{electrical degrees per cycle}}{\text{pairs of poles}}$$

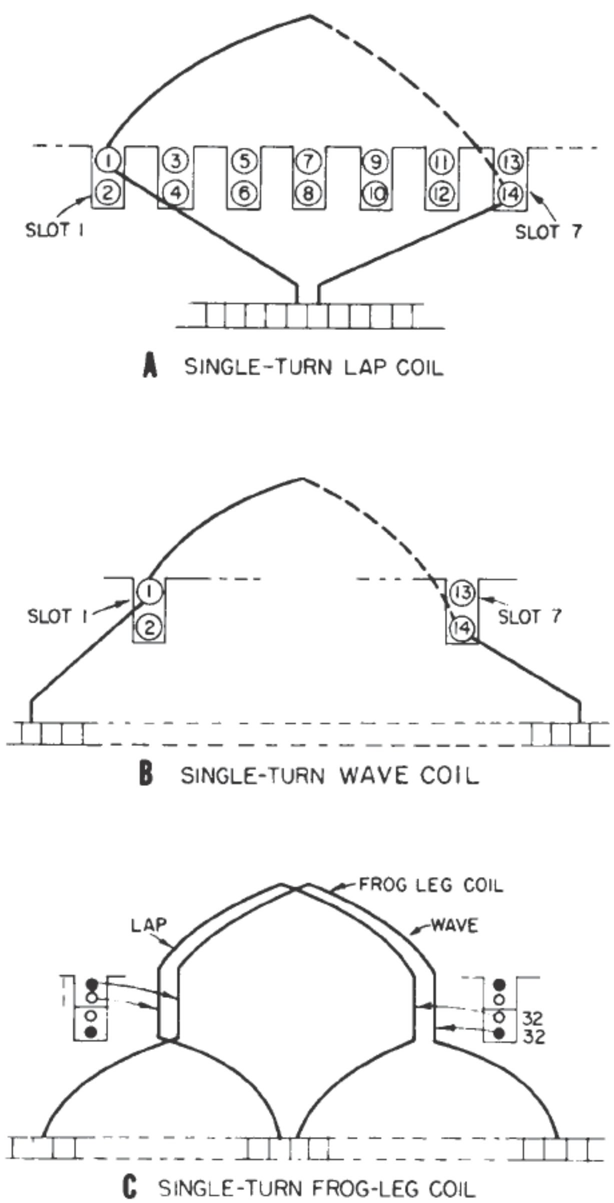
For example in a 2-pole, d-c winding there are 360 mechanical degrees for each 360 electrical degrees. In a 4-pole winding, there are $\frac{360}{2}$ or 180 mechanical degrees for each 360 electrical degrees. In a 6-pole winding there are $\frac{360}{3}$ or 120 mechanical degrees for 360 electrical degrees.

CHARACTERISTICS OF D-C ARMATURE WINDINGS

All armature windings are either of the closed-coil or open-coil types. The CLOSED-COIL winding has a continuous path through the armature that forms a closed circuit by reentering on itself. The OPEN-COIL winding has a continuous path through the armature but the winding does not reenter on itself. All d-c windings are of the closed-coil type, and most a-c windings are of the open-coil type.

CLASSIFICATION

Armature windings, irrespective of how the elements are placed on the armature core, are generally classified as LAP or WAVE windings. The classification designates the method of connecting the ends of the elements, or coils, to the commutator (fig. 2-1). If the ends of the coil are connected to adjacent commutator segments, or to segments that are close together, the coil is designated as a lap-connected coil, and the winding is a lap winding (fig. 2-1A). On the other hand, if the ends of a coil are connected to commutator segments approximately two pole pitches apart, the coil is designated as a wave-connected coil, and the winding is a wave winding (fig. 2-1B). Pole pitch will be described later. In some machines a combination lap and wave winding is placed on one armature to obtain the advantages of both classes of windings (fig. 2-1C). This winding



111.1

Figure 2-1.—Classification of armature windings.

is called a FROG-LEG winding because the coil ends resemble a frog's leg.

Both lap and wave windings are placed on the armature core so that the two sides of an element occupy slots that are influenced by adjacent poles of opposite polarity, and the emf's generated in the two sides add together. In other words, if the left side of a coil momentarily occupies a position under the center of a north pole, the right side of the same coil will occupy a position under approximately the center of an adjacent south pole. The distance between the centers of two adjacent poles is the pole pitch. The span of one coil should be equal or nearly equal to one pole pitch. If a coil spans exactly one pole pitch, the winding is FULL PITCH (fig. 2-2), and if a coil spans less than one pole pitch, the winding is FRACTIONAL PITCH. A fractional pitch winding should not be less than 0.9 of full pitch.

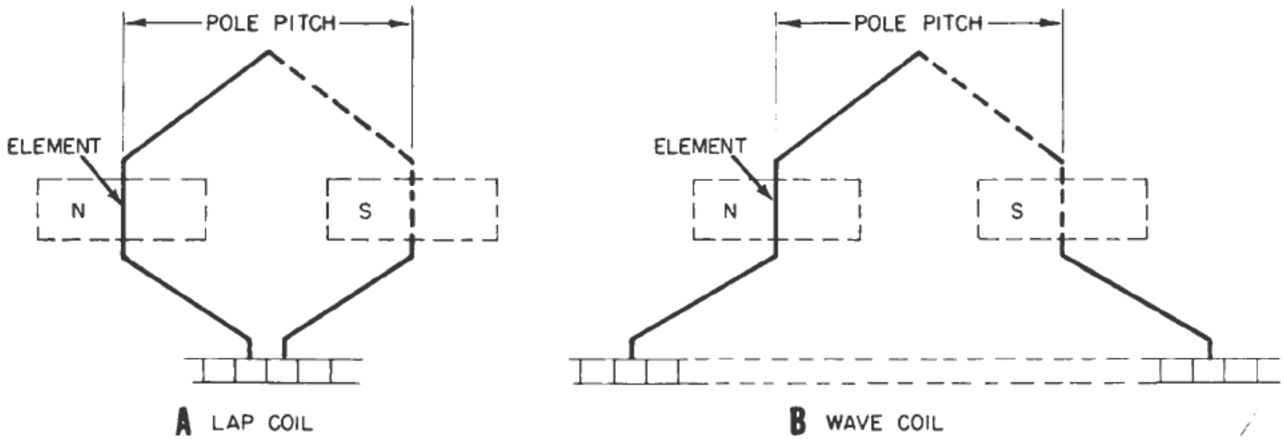
D-c armature windings are usually two-layer windings in which each slot contains two coil sides of a single-coil type of winding (fig. 2-1). Thus one side of the winding element is placed in the top of a slot, and the other side is placed in the bottom of another slot. It is immaterial which side of the element is placed in the top or bottom of the slot. In practice (observing the armature from the commutator end) the right side of the coil is usually placed in the bottom of one slot and the left side is placed in the top of another slot. The coil sides are arbitrarily numbered so that all TOP coil sides have odd numbers and all BOTTOM coil sides have even numbers (fig. 2-1). This system helps to place the coils properly on the armature.

PROGRESSIVE AND RETROGRESSIVE WINDINGS

Lap and wave windings can be progressive or retrogressive, as illustrated in figure 2-3.

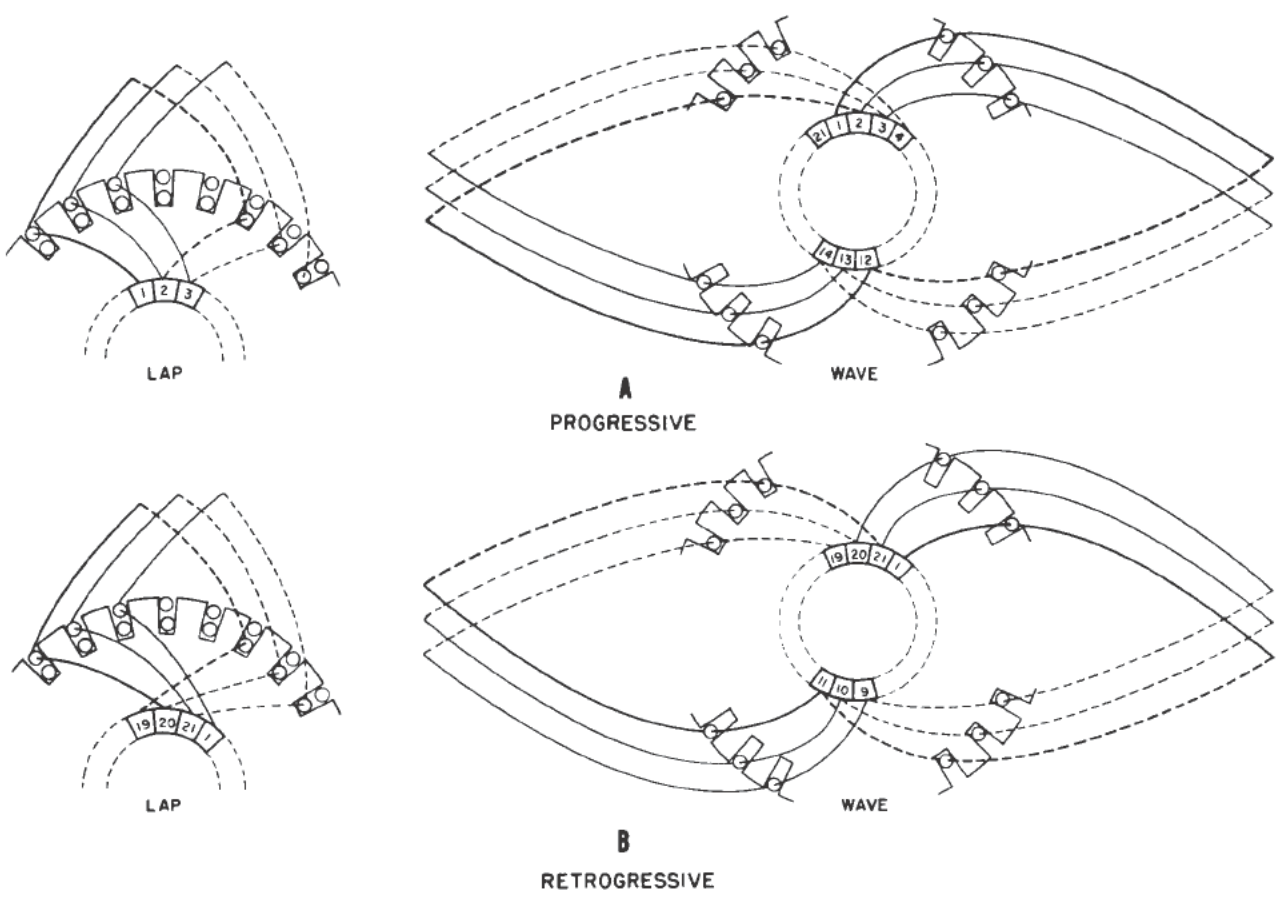
A PROGRESSIVE WINDING (fig. 2-3A) progresses in a clockwise direction around the armature when traced through the winding from the commutator end. In other words, the winding progresses clockwise from segment to element and element to segment. Notice that the end connections of a coil to adjacent commutator segments do not cross in the progressive lap winding but do cross in the progressive wave winding.

A RETROGRESSIVE WAVE WINDING (fig. 2-3B) progresses in a counterclockwise direction around the commutator when traced through the winding in a clockwise direction from the commutator end. A retrogressive lap winding progresses in a counterclockwise direction around the commutator when traced through the winding in a counterclockwise direction from the commutator end. Notice that the end



111.2

Figure 2-2.—Full-pitch coils.



111.3

Figure 2-3.—Progressive and retrogressive windings.

connections to the commutator cross in the retrogressive lap winding but do not cross in the retrogressive wave winding.

Progressive wave windings and retrogressive lap windings are very seldom encountered because of the inherent undesirable features, such as the end connections of coil groups crossing over each other, added weight, and longer leads. Therefore, with few exceptions lap windings are progressive and wave windings are retrogressive.

REENTRANCY AND MULTIPLICITY

Lap and wave windings are further classified as (1) simplex single reentrant, (2) duplex single reentrant, and (3) duplex double reentrant.

Reentrancy is the number of times that a winding closes on itself. If all the coils form one complete loop, the winding is SINGLE REENTRANT, and if the winding forms two separate complete loops that are insulated from each other, the winding is DOUBLE REENTRANT.

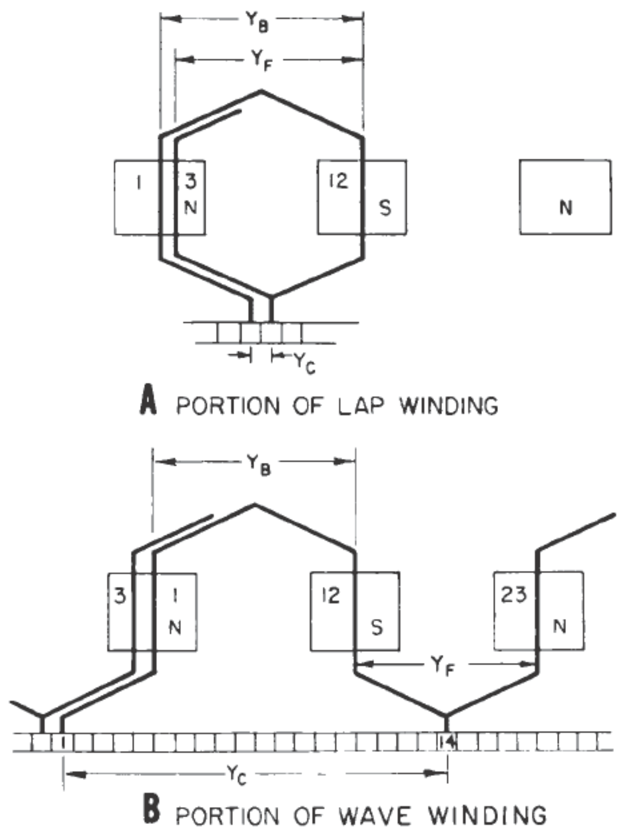
Multiplicity, or plex, is the number of separate circuits required to complete the total winding. Thus, a SIMPLEX WINDING consists of a single winding, and a MULTIPLEX WINDING consists of two or more windings in parallel.

A simplex lap winding has as many armature circuits in parallel as there are poles, P. Thus, a duplex lap winding has 2P armature circuits in parallel, and a triplex lap winding has 3P parallel armature circuits. On the other hand, a simplex wave winding has only two paths through the armature irrespective of the number of poles. Thus, a duplex wave winding has four parallel circuits, and a triplex wave winding has six parallel circuits. Hence, lap windings are often called parallel or multiple circuit windings, and wave windings are called series, or two-circuit, windings.

The BACK PITCH, Y_b, of a lap or wave winding (fig. 2-4) is the number of winding elements (coil sides) that a single coil spans at the back of the armature. In both portions of the lap (fig. 2-4A) and wave (fig. 2-4B) windings $Y_b = 12 - 1 = 11$.

The FRONT PITCH, Y_f, of a lap or wave winding is the number of elements between two elements connected to a common segment of the commutator. In figure 2-4A, $Y_f = 12 - 3 = 9$, and in figure 2-4B, $Y_f = 23 - 12 = 11$.

The COMMUTATOR PITCH, Y_c, is the number of commutator segments spanned by the two



111.4
Figure 2-4.—Portion of lap and wave windings.

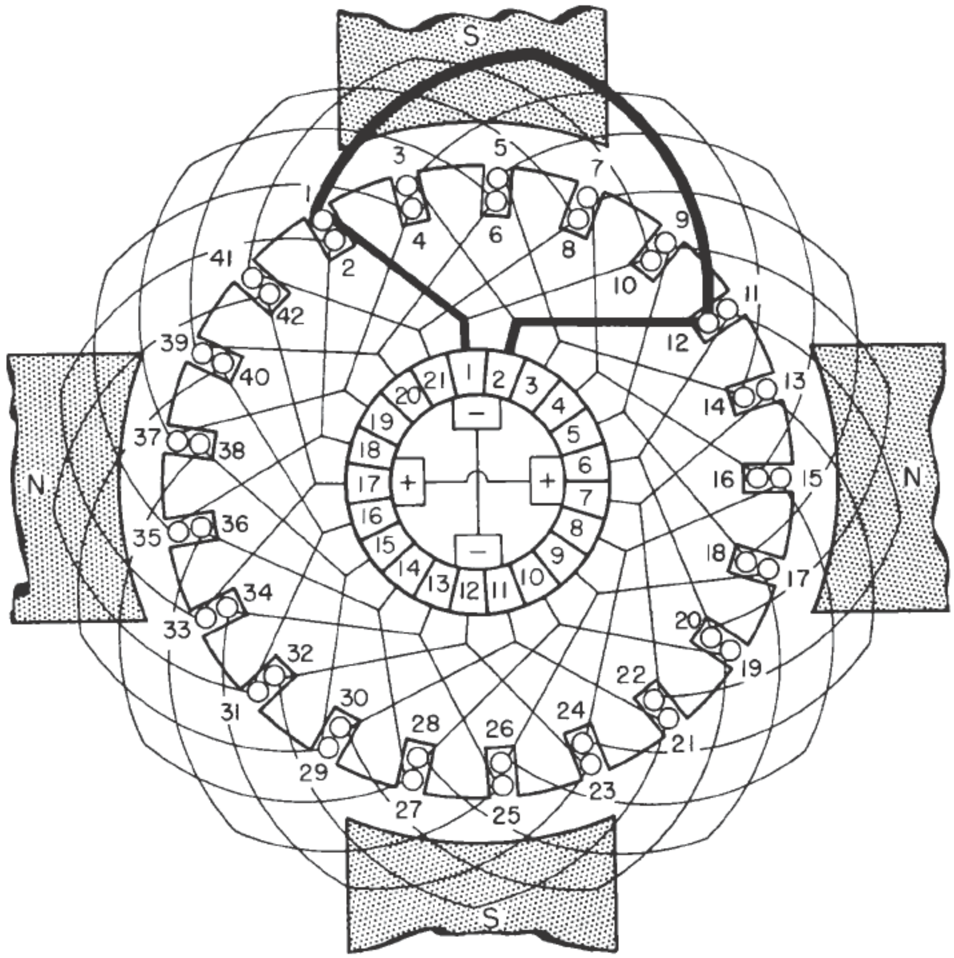
ends of the same coil. In figure 2-4A, $Y_c = 2 - 1 = 1$, and in figure 2-4B, $Y_c = 14 - 1 = 13$.

LAP WINDINGS

As previously stated, d-c lap windings can be simplex single reentrant, duplex double reentrant, and duplex single reentrant, and are closed-circuit windings. Hence, the coils must form a complete loop so that the winding reenters itself.

A simplex lap winding consists of one winding with all the coils connected together to form one complete loop. Because there is only one winding it can reenter or close on itself only one time. Hence, all simplex lap windings must be single reentrant.

A 4-pole, simplex single-reentrant lap winding is illustrated in figure 2-5. The ends of each coil are connected to adjacent commutator segments. For example, coil 1 - 12 begins at



111.5

Figure 2-5.—Simplex single-reentrant lap winding.

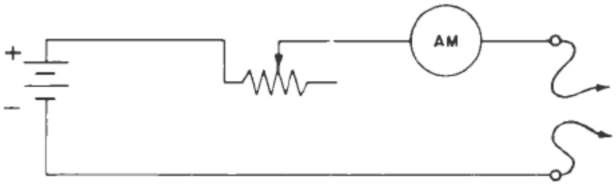
segment 1 and ends at segment 2. Adjacent coil 3 - 14 begins at segment 2 and ends at segment 3. Thus two coil ends are connected to each commutator segment. Start at segment 1 and trace through the coil to the adjacent segment 2, then continue through all the coils in succession until the winding reenters segment 1. The winding is single reentrant because when traced through all the coils, it reenters itself only once. In this case, the number of coils is equal to the number of armature slots, which in turn, is equal to the number of commutator segments.

When an armature is assembled in the machine, the winding is divided into paths by the brushes. The connections for a simplex lap winding are the same whether the machine has 2, 4, 6, or any even number of poles. A lap winding requires one brush for each pole, and the brushes are always equally spaced around the commutator. Thus, a 4-pole, simplex single-reentrant lap winding has four brushes spread 90° apart (fig. 2-5). The total current entering a brush divides into two paths so that there are four parallel paths through the armature. There must be as many brushes as there are poles because the current divides equally through the brushes, and if any one brush is lifted or removed, in this example, only half the winding is utilized. In all simplex lap windings there are as many paths through the armature as there are poles.

Lap windings on very large machines frequently contain equalizer connections to equalize the voltage between parallel sections of the winding to prevent circulating currents from flowing through the brushes and the commutator. Only lap windings have equalizer connections but they are difficult to identify when inspecting an armature. On lap windings not using equalizer connections, other methods are necessary to identify them.

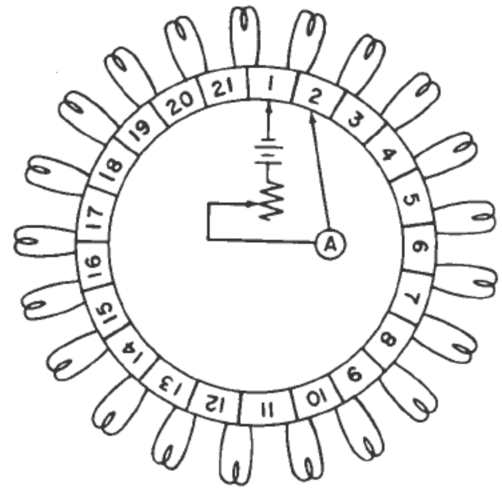
It is important to identify armature windings because the type must be determined in order to understand the trouble indications and to make the necessary repairs. One method is to use a low-reading ohmmeter to indicate variations in the resistance readings as the test probes are shifted around on the commutator. If a low-reading ohmmeter is not available, a milliammeter connected in series with a rheostat and a 6-volt battery can be used (fig. 2-6).

A schematic diagram of a simplex single-reentrant lap winding is illustrated in figure 2-7. With the test probes placed on adjacent segments, the ammeter will indicate a maximum because the resistance of only one coil shunts the remainder of the winding, and the resistance added to the test circuit is at minimum. Move one test probe to the next segment, and the ammeter reading decreases because the resistance between the probes has increased. With one probe stationary and the other probe contacting each segment in succession around the commutator, the armature indications will decrease steadily until the test probes are directly opposite each other, and then start increasing steadily as the other half of the winding is tested. These indications are obtained because of the method of connecting the coils to the commutator, which is determined by the type of winding. A simplex lap winding is the only winding that gives these indications.



111.6

Figure 2-6.—Test circuit for measuring armature.



111.7

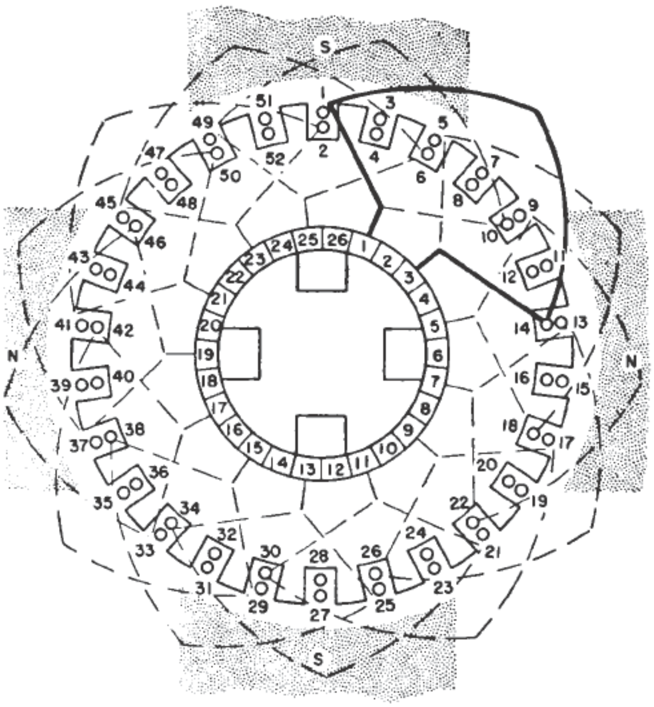
Figure 2-7.—Schematic diagram of simplex single-reentrant lap winding.

Duplex Double-Reentrant Lap Winding

A duplex lap winding has the ends of the coils connected to alternate commutator segments. The coils are placed in the slots according to the number of poles for which the armature is wound. The only difference between the simplex and duplex lap windings is the method of connecting the coils to the commutator. When a duplex lap winding is connected to a commutator with an even number of segments, the winding is double reentrant. When a duplex lap winding is connected to a commutator with an odd number of segments, the winding is single reentrant.

One of the two identical windings of a 4-pole, duplex double-reentrant lap winding is illustrated in figure 2-8. The duplex double-reentrant winding consists of two windings that are closed loops and insulated from each other. The coils of one winding are connected to the odd commutator segments, and those of the other winding are connected to the even segments.

A duplex double-reentrant lap winding (fig. 2-9) can be identified by the same method described to identify a simplex single-reentrant lap winding. Because the two windings of a duplex double-reentrant lap winding are insulated from each other, the test ammeter reads zero when the probes are placed on adjacent segments (fig. 2-9). When the probes are placed on alternate segments, the meter will



111.8
Figure 2-8.—One winding of 4 pole, duplex double-reentrant lap winding.

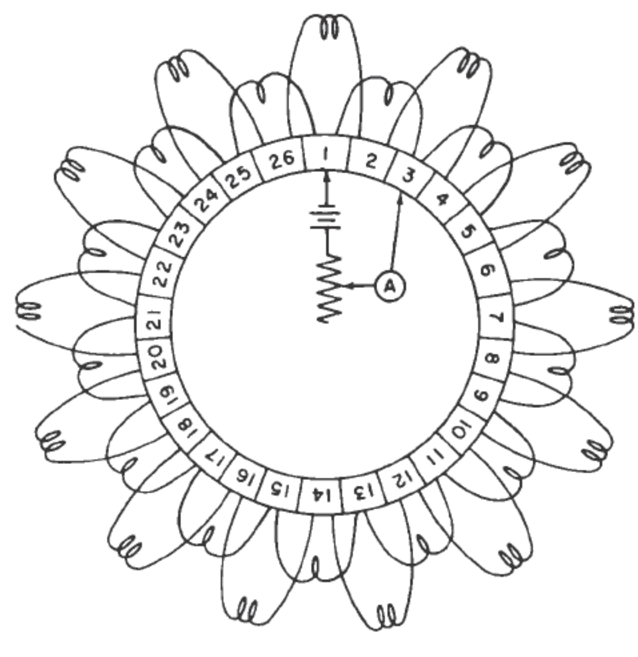
indicate the maximum reading because the resistance of only one coil shunts the remainder of the associated winding, and the resistance added to the test circuit is minimum. If one probe is held stationary and the other probe circled around the commutator, contacting alternate segments in succession, the readings will decrease until the probes are directly opposite each other, and then start increasing as the other half of the winding is tested. A duplex double-reentrant lap winding is very similar to two simplex lap windings on one armature. The principal difference is that the coil ends of each coil are connected to alternate instead of adjacent commutator segments.

As previously stated, a simplex lap winding requires as many brushes as there are poles, and the brushes divide the winding into as many paths through the armature as there are poles. In a duplex lap winding, the brushes divide the winding into twice as many paths as there are poles. It is necessary for each brush to span, or contact, at least two commutator segments because one winding is connected to the even numbered segments and the other winding to the odd numbered segments. However, a brush width of two segments does not necessarily indicate the multiplicity of a winding because simplex windings sometimes have brushes that span two segments.

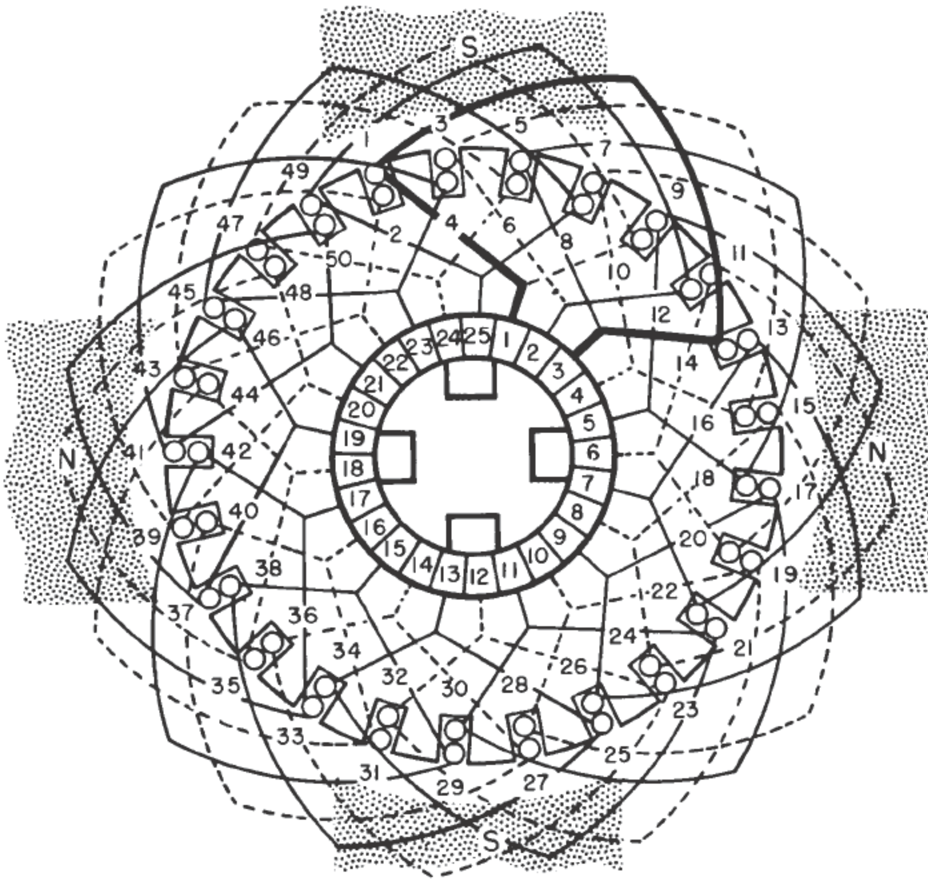
The number of paths through the armature in a lap winding can be determined by multiplying the number of poles, P, by the multiplicity, M. For example, in a 4-pole, duplex double-reentrant lap winding, the four brushes will divide the armature coils of each winding into four paths so that there will be a total of 4 poles times 2 plex, or 8 paths through the armature.

Duplex Single-Reentrant Lap Winding

A 4-pole, duplex single-reentrant lap winding is illustrated in figure 2-10. It is a duplex lap winding because the ends of each coil are connected to alternate commutator segments, and it is single reentrant because both windings are connected together to form one closed loop. Start at segment 1 and trace through the coil to the alternate segment 3, then continue through all the coils in succession until the winding reenters segment 1.



111.9
Figure 2-9.—Schematic diagram of 4-pole, duplex double-reentrant lap winding.



111.10

Figure 2-10.—Four-pole, duplex single-reentrant lap winding.

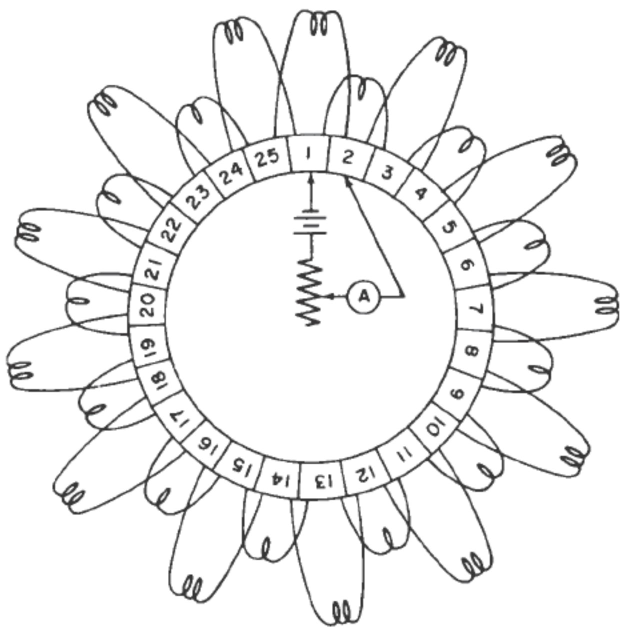
To identify a duplex single-reentrant lap winding (fig. 2-11), place the test probes on adjacent segments. The ammeter indication will be minimum because the number of coils and the resistance in each of the two parallel paths through the winding are maximum. If one probe is placed on an alternate segment, the ammeter will indicate maximum because the resistance of only one coil shunts the remainder of the winding, and the resistance added to the test circuit is minimum. With one probe stationary on segment 1 and the other probe contacting alternate odd segments 3, 5, 7, and so forth around the commutator, the ammeter indications will decrease steadily as the commutator is circled once. The ammeter indications will increase steadily as the commutator is circled the second time, contacting the alternate even segments 2, 4, 6, and so forth.

Both a duplex single-reentrant lap winding and a duplex double-reentrant lap winding have maximum indications on alternate segments and minimum indications on adjacent segments.

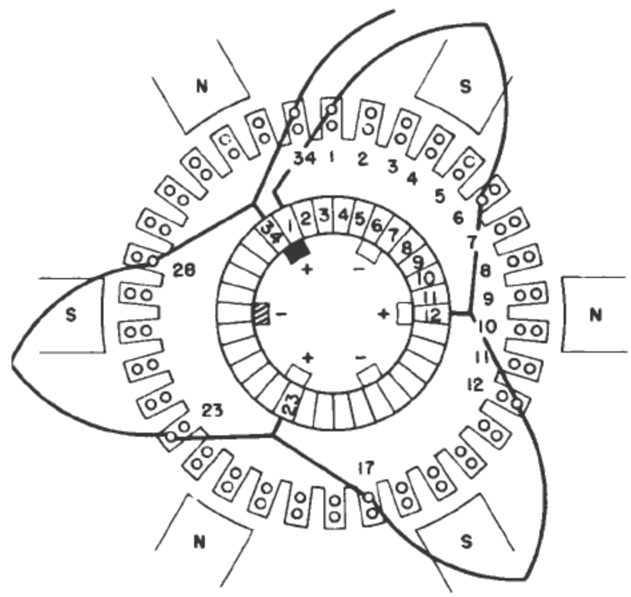
Each brush in a duplex single-reentrant lap winding, similar to a duplex double-reentrant lap winding, must span at least two segments to connect both windings to the external circuit at all times and to divide both windings into parallel paths through the armature. As in all lap windings the number of paths through the armature is obtained by multiplying the number of poles, P, by the multiplicity, M. In other words, the brushes should span as many commutator segments as the plex of the winding.

WAVE WINDINGS

Wave windings, similar to lap windings, can also be simplex single reentrant, duplex double



111.11
Figure 2-11.—Schematic diagram of 4-pole, duplex single-reentrant lap windings.



111.12
Figure 2-12.—Portion of 6-pole, simplex single-reentrant wave winding.

reentrant, and duplex single reentrant. However, an important rule for all wave windings is that the ends of each coil are connected to commutator segments that are approximately two pole pitches apart. The distance from the center of one pole to the center of the next pole of the same polarity is two pole pitches. Thus, in a 4-pole machine two pole pitches are one-half the distance around the commutator, in a 6-pole machine, one-third the distance around the commutator, and in a 8-pole machine, one-fourth the distance around the commutator.

Simplex Single-Reentrant Wave Winding

A simplex wave winding consists of one winding with the coil ends connected approximately two pole pitches apart to form one complete loop.

In the simplex wave winding there are as many coils connected in series between adjacent commutator segments as there are pairs of poles, $\frac{P}{2}$. For example, a 34-slot armature (fig. 2-12) is to contain a 6-pole, simplex single-reentrant wave winding. Because there are three pairs of poles, there are three coils connected in series between adjacent commutator segments, and the ends of each coil are connected to segments approximately one-third the distance around the commutator (two pole pitches apart).

Any armature winding can be identified by use of the previously mentioned test circuit (fig. 2-6). The maximum ammeter reading is indicated when the test probes are connected across that portion of the winding in which one coil shunts the remaining portion of the winding. Hence, in all wave windings the maximum reading will be indicated when the probes are placed on commutator segments that are approximately two pole pitches apart. The minimum ammeter reading will occur when the probes are placed on segments approximately one pole pitch apart.

With one probe stationary on segment 1 (fig. 2-12) and the other probe moved around the commutator from segment to segment (2, 3, 4, and so forth), the ammeter readings steadily decrease until the probes are approximately one pole pitch apart, and then the readings steadily increase until the probes are approximately two pole pitches apart.

If the probe is circled around the remainder of the commutator, the readings will decrease

and then increase once for each pair of poles. In the identification of a 6-pole, simplex wave winding there will be three successive decreases and increases in the meter readings as the commutator is circled once. Similarly, in a 4-pole simplex wave winding there will be two successive decreases and increases in the meter readings.

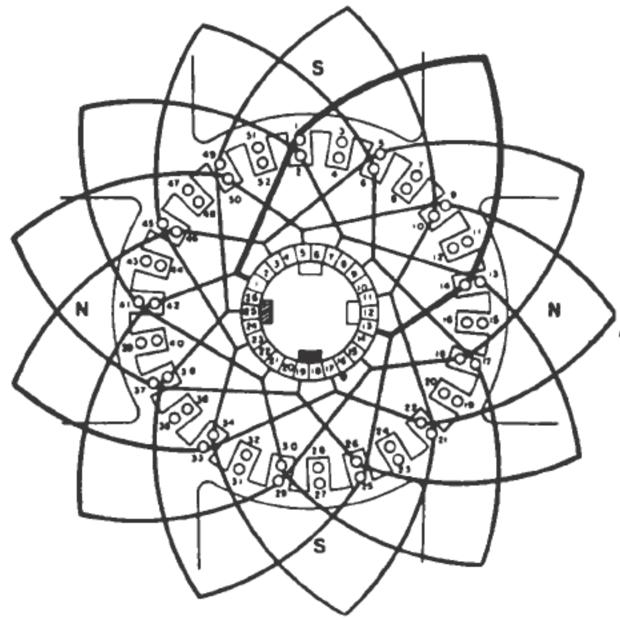
In the 6-pole, simplex wave winding (fig. 2-12) there are six brushes, but the winding is divided into only two paths through the armature. If four brushes, two of each polarity, are removed from the commutator there are still only two paths through the armature. Therefore, any simplex wave winding has only two paths through the armature irrespective of the number of poles for which it is wound and irrespective of the number of brushes.

Thus, a simplex wave winding can be readily identified from a simplex lap winding by measuring the resistances of the armature coils. The windings can also be identified by observing the method of connecting the coils to the commutator segments. Observe the commutator end of a simplex lap winding (fig. 2-5). If a commutator lead goes to an armature slot that lies counterclockwise from the commutator segment, the back turns from the coil side will go in a clockwise direction. Now observe the commutator end of a simplex wave winding (fig. 2-12). If a commutator lead goes to an armature slot that lies clockwise from the commutator segment, the back turns of that coil side will also go in a clockwise direction. However, whenever practicable, take resistance measurements to identify the winding because it is not always possible to determine the direction of the coil leads and coil sides in a finished armature.

Duplex Double-Reentrant Wave Winding

A duplex wave winding consists of two complete windings. The coil ends are connected approximately two pole pitches apart as in the simplex wave winding. The principal difference in the two windings is that in the duplex wave winding the series of coils are connected to alternate segments, whereas in the simplex wave winding the coils are connected to adjacent segments.

A 4-pole, duplex double-reentrant wave winding showing one of the two associated windings is illustrated in figure 2-13. Because there are two pairs of poles, two coils are connected in series between any two alternate segments. The ends of each coil are connected to segments that are spaced approximately one-half the distance around the commutator (two pole pitches apart).



111.13
Figure 2-13.—One of two windings of 4-pole, duplex double-reentrant wave winding.

Approximately the same meter indications will be obtained when identifying a duplex double-reentrant wave winding as were obtained for a simplex wave winding. The principal difference is that a zero indication will be obtained when the test probes are placed on adjacent commutator segments, and all other indications will have to be taken on alternate segments.

There are four brushes any two of which divide each winding into two parallel paths so that there is a total of four paths through the armature. Because there are only two paths through any wave winding and because an armature can consist of more than one winding, the number of paths through a wave winding is obtained by multiplying the constant 2 (paths) by the multiplicity M.

Duplex Single-Reentrant Wave Winding

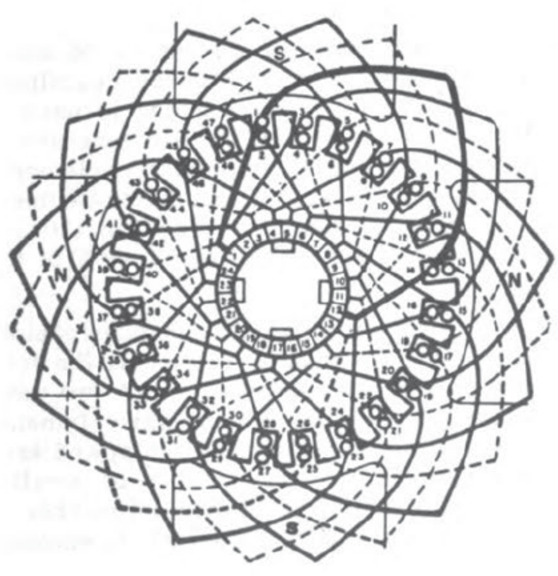
A duplex single-reentrant wave winding is somewhat similar to a duplex double-reentrant wave winding, except that the coils of the two windings are connected together to form one closed loop.

A 4-pole, duplex single-reentrant wave winding is illustrated in figure 2-14. When the winding is identified by the resistance method, the minimum ammeter indication (maximum resistance) is obtained when the test probes are placed on adjacent segments. The maximum indication is obtained when the probes are placed on segments that are approximately two pole pitches apart. These indications differ from the indications obtained for any other type of winding and thus identify a duplex single-reentrant wave winding.

The brushes in a duplex single-reentrant wave winding, similar to a duplex double-reentrant wave winding, must span at least two commutator segments at all times, and both have their coils divided into the same number of parallel paths through the armature.

Dummy Elements

In some armatures the ratio of the number of commutator segments to the number of slots is not always a whole number. If a wave winding is placed on such an armature, a DUMMY element is necessary on the armature. A dummy element is placed on the armature to maintain mechanical balance but has no electrical function. The ends of this element, which are not connected to the commutator, are cut off close to the core, taped, and left open circuited.



111.14
Figure 2-14.—Four-pole, duplex single-reentrant wave windings.

Winding Identification

The most common types of armature windings have been discussed to acquaint the Electrician's Mate with each type and to show how it differs from the others. As previously stated, the type of winding varies with the method of connecting the coil ends to the commutator segments. The factors necessary to identify a winding are (1) reentrancy, (2) multiplicity, (3) type (lap or wave), and (4) number of poles for which it is wound.

The application of the following rules will identify an armature winding when the test circuit (fig. 2-6) is used:

1. The winding is single reentrant if a (current) reading is indicated when the test probes are placed on adjacent segments.
2. The winding is double reentrant if a zero, or very low, indication is obtained when the probes are placed on adjacent segments.
3. The winding is simplex if the indication decreases when moving one probe from adjacent to alternate segments (within one pole pitch).
4. The winding is duplex if the indication increases when moving one probe from adjacent to alternate segments.
5. Identify the winding as lap or wave using table 2-1.

By applying the above information, an Electrician's Mate should be able to identify any Navy armature.

Equalizer Connections

Ordinary operation of large electrical machines causes the bearing to wear, resulting in an unequal air gap between the coil and the pole pieces so that the flux in some poles becomes greater than in others. For lap windings, this condition causes the voltages generated in the various circuits to become unequal. This action causes heavy circulating currents to flow between the unbalanced portions of lap windings. These circulating currents tend to heat the armature and cause undue sparking at the brushes because the currents must circulate from one path to another across the brush contacts.

In a 4-pole simplex lap-wound machine, four different voltages would be generated in the four paths if all the air gaps were unequal and each

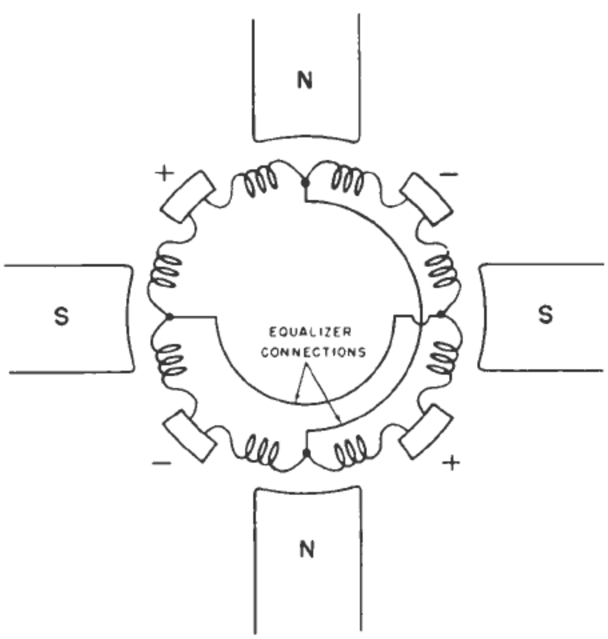
Table 2-1.—Armature Identification Chart.

Type	Lap Winding		Wave Winding	
Series Current Readings	Maximum	Minimum	Maximum	Minimum
Simplex	Adjacent segments	Opposite segments	Two pole pitches	One pole pitch
Duplex single reentrant	Alternate segments	Adjacent segments	Do	Adjacent segments
Duplex double reentrant	Do	Opposite segments*	Do	One pole pitch

*Adjacent segments test open unless one is dead (shorted out).

path contained the same number of elements. The output voltage between the positive and negative sets of brushes must be a compromise of these different voltages, which results in an exchange of current from one path to another. In a wave winding two or more groups of coils generate equal voltages at the same time. Because these coil groups are connected in series rather than in parallel (as the lap winding) there are no circulating currents.

The detrimental effects resulting from circulating currents passing through the brushes are corrected by using equalizer connections (fig. 2-15). Equalizer connections tie together points on the armature that should, under ideal conditions, be at the same potential. They connect together points on the winding or on the commutator segments that are exactly two pole pitches apart. The equalizer connections provide a low-resistance path for the circulating current that occurs when differences of potential exist and thus improve commutation by bypassing the commutator and brushes.



111.15
Figure 2-15.—Equalizer connections.

A lap winding can have many equalizer connections, but usually connections to one-third of the winding or segments are sufficient.

If the equalizer connections are connected directly to the coils, a tap is run from one turn of the coil to a ring mounted at the end of the armature opposite the commutator. The number of rings varies with the winding and the amount of desired equalization. Another method (used on small armatures) is to connect jumpers directly to the commutator segments. In either case, the equalizer connections provide a low-resistance path for the circulating current caused by unequal voltages being generated in the coils that should be at the same potential.

FROG-LEG WINDINGS

As previously stated, a frog-leg winding consists of a combination lap-wave winding placed on one armature (fig. 2-1C).

This winding has the advantage of many paths for current (lap) and 100 percent equalization (wave). The frog-leg winding is used in propulsion systems employing d-c generators. The slots contain both the lap and wave elements of the winding, and each commutator-segment riser has four connections, two for the lap element and two for the wave element of the windings.

If an armature has the same number of slots as commutator segments, there will be four elements or four coil sides in each slot, two wave and two lap. Also, if the lap and wave elements are each considered to form distinct lap and wave windings respectively, the number of parallel paths in the lap winding must equal the number of paths in the wave winding because both windings are in parallel with each other.

In a frog-leg winding the lap section is always simplex, and the wave section always has a plex of $\frac{P}{2}$. This is the only combination that will produce satisfactory operation because a simplex

lap winding has as many paths as there are poles, and a wave winding with a multiplicity of $\frac{P}{2}$ also has as many paths as there are poles. Frog-leg windings have as many circuits in parallel as duplex lap windings because the simplex lap section supplies P circuits, and the multiplex wave section also supplies P circuits, giving a total of 2P circuits in parallel. The sections are identical electrically, and thus each section carries half the total load.

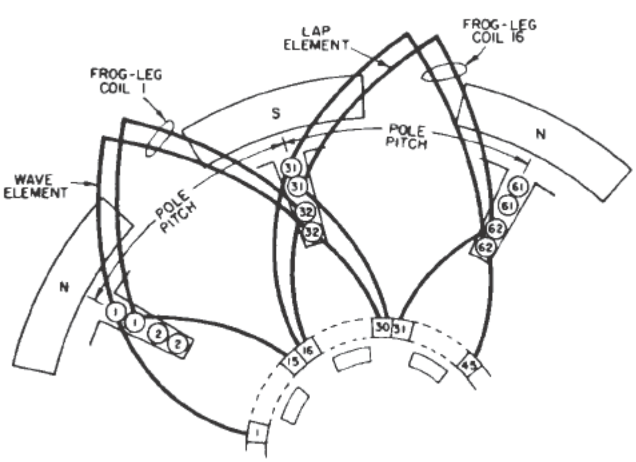
A portion of a 6-pole, frog-leg winding is illustrated in figure 2-16. For simplicity, only two of the frog-leg coils are shown.

Start at segment 1 and trace through the wave and lap elements to segment 31, two pole pitches apart. If the armature is rotating, the voltage generated in the wave coil sides 1 and 32 is equal and opposite to the voltage generated in the lap coil sides 31 and 62.

The two equal and opposite voltages cancel each other so that the net voltage between segments 1 and 31 will be zero. Hence, the wave winding eliminates the need for an equalizer connection on the lap winding.

The number of brush positions on the commutator is similar to that for a lap winding.

Frog-leg windings are difficult to identify by resistance measurements, but because they are used only in large machines they can be readily identified by observing the characteristic shape (frog leg) of the leads to the commutator.



111.16
Figure 2-16.—Portion of 6-pole, frog-leg winding.

REWINDING ARMATURES

The most common troubles encountered in d-c armature windings are grounds, opens, and shorts.

TESTS

The most practical and accurate method of locating these faults is the bar-to-bar test, which consists of comparing the resistance (in terms of the IR drops) of the armature coils. The bar-to-bar tests for locating grounds, opens, and shorts in d-c windings are described in chapter 5 of Electrician's Mate 3 and 2, NavPers 10546-A. In addition to this information, reference to table 2-2 will provide valuable supplementary material when conducting bar-to-bar tests.

A growler (fig. 2-17) can be used to detect and locate grounds, opens, and shorts in small armatures. The device consists of a coil of wire wound around an H-shaped, laminated iron core. The laminations on top are cut out to hold the armature under test between the two poles of the growler. When an alternating current is applied to the coil, an emf will be induced in the armature coils by transformer action.

To test an armature for grounds with the growler, place the armature on the poles of the growler and energize the coil from a 115-volt source. Connect one lead of an a-c millivoltmeter to the armature shaft and use the other lead as a probe, contacting each commutator segment one at a time in sequence (fig. 2-17A). If there are no grounds in the winding, no reading will be indicated on the meter because the commutator is insulated from the shaft. If there is a ground in the winding, a reading will be indicated on the meter for all good coils (fig. 2-17B). No reading on the meter indicates that the grounded coil is connected to this segment.

To test an armature for shorted coils with the growler, place the armature on the growler and turn on the current. Hold a hacksaw blade directly over, and along the length of, the top slot. If the coil in this slot is shorted, the blade will vibrate rapidly and cause a growling noise. If the blade does not vibrate, it is an indication that no short exists in the coil. Test each slot in sequence by turning the armature so that the slot to be tested is on top.

To test a simplex lap or wave armature for opens with the growler, set up the armature on the growler in the usual manner. Test the top

Table 2-2. —Armature Testing Chart.

Classification	Apply Potential To—	Test—	Opens	Shorts	Grounds
Simplex single lap	Directly opposite bars.*	Adjacent bars.	One indication which is very high, or full-scale reading for each open.	One indication which is zero, or a very low reading for each short.	Two indications —one real and one phantom. They are zero or very low readings followed by a reversal at the next bar. Test from bar to ground by holding one test probe on the shaft and moving the other from bar to bar.
Duplex single lap	Adjacent bars.	Alternate bars.	Do.	Do.	Do.
Duplex double lap	Directly opposite odd bars; then to directly opposite even bars.	Do.	Do.	Do.	Do.
Simplex single wave	Bars that are one pole space apart.	Adjacent bars.	As many indications as pairs of poles. They are very high or full-scale readings.	As many indications as pairs of poles. They are zero or a very low reading.	As many indications as poles. One half of them are real, and the other half are phantom. Indications are zero or very low readings followed by a reversal at the next bar.
Duplex single wave.	Adjacent bars.	Alternate bars.	Do.	Do.	Do.
Duplex double wave	Odd or even bars that are one pole space apart.	Do.	Do.	Do.	Do.

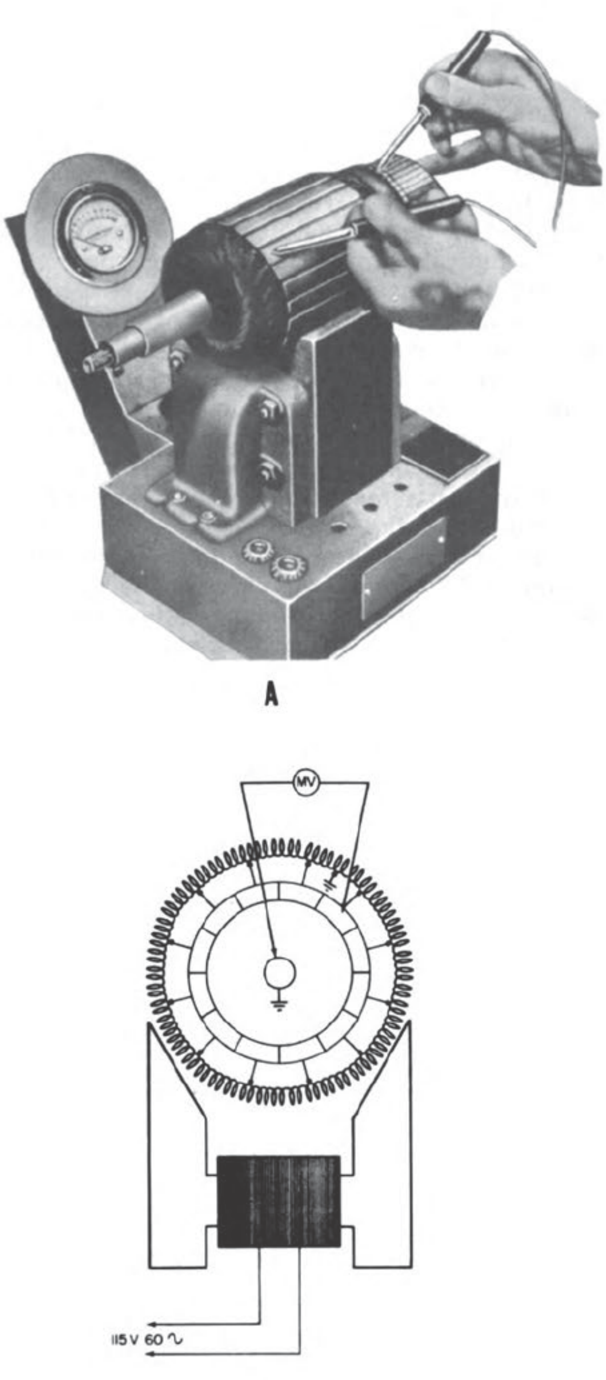
*Assume no equalizer connections.

two adjacent segments with an a-c millivoltmeter. Turn the armature and continue testing the two top adjacent segments. A reading will be indicated on the meter of all segments that are connected to good coils. No reading on the meter indicates an open coil between the two segments.

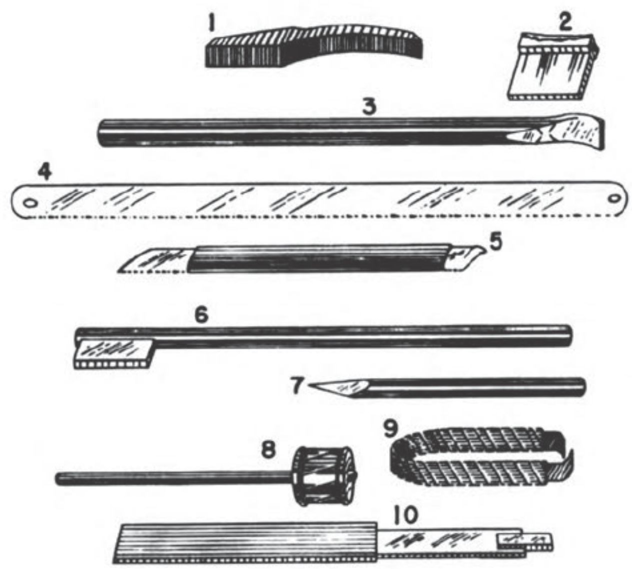
The Bureau of Ship's Technical Manual, chapter 60, and other applicable Bureau of Ships publications list specific instructions to be followed by personnel engaged in rewinding and reconditioning armatures and field coils. However, the general procedures to be followed when performing this work on class A and class B insulated motors and generators are included for the convenience of those who may not have access to these manuals. The classes of insulating materials have been described in chapter 2 of the training course, Electrician's Mate 3 and 2, NavPers 10546-A.

HANDTOOLS

The handtools used in rewinding armatures are relatively few and simple. In fact, they are usually handmade by Electrician's Mates engaged in this work aboard repair ships and at shore stations. Figure 2-18 shows the following tools: (1) fiber horn for shaping the coil ends after the coils are placed in the slots, (2)



2.92
Figure 2-17.—Growler.



111.17
Figure 2-18.—Armature rewinding hand tools.

steel slot drift, or tamping tool, for driving the coils to the bottom of partly closed slots, (3) lead lifter for lifting the coil leads from the commutator risers, (4) hacksaw blades for removing the fiber wedges that hold the coils in the slots, (5) saw for undercutting the commutator mica between the segments, (6) wedge driver for driving the fiber wedges out of the slots, (7) lead drift for cutting off the leads at the risers, (8) rotation indicator as an aid to determine the proper connections of the windings, (9) wire scraper for removing the insulation from the ends of the coil leads, and (10) wedge inserter for driving the wedges into partly closed slots.

Stripping

Before stripping an armature, record all available winding data on an armature data card, as shown in figure 2-19 for use in rewinding and for future reference.

After recording the initial winding data, perform a bar-to-bar test to determine if the winding is lap or wave and record this information on the armature data card.

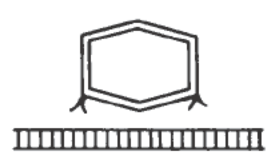
If it is necessary to rewind the armature, first disconnect and remove the coils.

During this process, accumulate the winding data that was impossible to obtain before stripping the armature. Remove the banding wires by filing them in two places. If banding wires are not used, remove the wedges in the slots. A simple means of removing the wedges is to place a hacksaw blade, with the teeth down, on the wedge. Tap the top of the blade to set the teeth in the wedge and then drive out the wedge by tapping the end of the blade. Perform a bar-to-bar test to determine the fault. If a short is indicated, disconnect the top commutator leads and make an insulation test between the commutator segments. If a short is located, disconnect the bottom commutator leads and test to determine whether the short is in the coil or in the commutator. If the short is in the commutator, reinsulate the defective segments, then reconnect the commutator leads and make another bar-to-bar test to determine if any trouble exists in either the winding or the commutator.

Next, unsolder the coil leads from the commutator and raise the top sides of the coils the distance of a coil throw (distance between the two halves of a coil). The bottom side of a coil is now accessible, and the other coils can be removed one after the other. Exercise care to preserve at least one of the coils in its original shape for use as a guide in forming the new

Make

K.W. H.P.	R.P.M.	Volts	Amps.
Cycle	Type	Frame	Style
Temp.	Model	Serial	Phase

No. of Slots	Bars	Coils/Slot
Size Wire	Coil Pitch	
Center of Slot to	Center of Bars Center of Mica	
Commutator Pitch Lap Wave		

111.18

Figure 2-19.—D-c armature data card.

coils. Next, record the wire size, number of turns in a coil, and type of insulation on the coils and in the slots.

To raise the coils without damaging the insulation, use a small block of wood as a fulcrum resting on the armature core and a steel bar or piece of wood as a lever.

After the coil is partly raised, drive a tapered fiber wedge between the top and bottom coils within the slot to finish raising the top coil from the slot. After stripping the armature, remove all dirt, grease, rust, and scale. File each slot to remove any burrs or slivers and clean the core thoroughly with compressed air. Immerse the cleaned armature core in a varnish and bake, using a dilute varnish (20 percent solution) of the same type of varnish to be used after winding.

This treatment prevents the formation of oxides and forms a base for the adherence of the final varnish treatment.

WINDING ARMATURE COILS

Formed coils are wound on a coil-winding machine and pulled into the desired shape on the forming machine. The shape of the coil is determined by the old coil. The two wires forming the leads are taped with cotton or reinforced mica tape. The binder insulation, consisting of cotton or glass tape, is applied to the entire coil surface.

The coil is now sprayed with a clear air-drying varnish (grade CA), which conforms to Military Specification, MIL-V-1137. After the varnish has dried, the coil ends are tinned to ensure a good connection to the commutator.

PLACING COILS IN SLOTS

The ground insulation, consisting of flexible mica wrappers or layers of reinforced mica tape is applied to the coil sides that lie in the slots. The formed coils are next placed in the slots, the lower side first and then the upper side, until all the coils are inserted and the winding is completed. Be certain that the coil pitch is correct. A strip of fuller board is placed in each slot between the lower and upper coil sides, and a similar strip is placed at the back and front of the armature where top and bottom sides cross each other. If the slots have straight sides, they are filled up with a strip of hard fiber on the tops of the coils so that they can be held down by the banding wires. In some armatures the slots are shaped so that fiber wedges can be driven in each slot from one end to hold the coils in place.

Before soldering the coil ends to the commutator segments, test the winding for grounds, opens, shorts, and dead coils. Exercise care (when soldering) to prevent solder from falling or running down the back of the commutator, as this would result in a short circuit. Tip the armature so that the solder will not flow down the back of the commutator. Place the tip of the soldering iron on the commutator near the riser and wait until the iron heats the riser sufficiently to melt the solder. Touch the solder to the riser and allow it to flow down and around the lead and into the wire slot, and then remove the iron.

The ordinary soldering iron cannot supply sufficient heat fast enough to perform a satisfactory soldering job on a large armature. Therefore, apply a soft flame from an acetylene torch to the outside end of the commutator segments so that the heat will travel along the segments to the riser ends where connections are made. Tin the coil ends (to be connected to the commutator risers) with the soldering iron. Next, tin the slots in the commutator risers with heat from the torch. Then make the connections while applying the flame to the outside end of the commutator segments. Wrap the winding in asbestos tape for protection (when making the commutator connections) because too much heat can damage the winding insulation. The completed armature winding is checked electrically for continuity and for shorted turns.

VARNISHING

The complete armature is now prebaked and varnish treated in accordance with the procedures listed in table 2-3. The coils and windings of practically all electrical equipment are required to be treated with at least three dips and bakes in an approved insulating varnish. For class A and class B insulation equipment for varnish used is grade CB (clear baking) of Military Specification MIL-V-1137.

D-c armatures should be dipped with the commutator end up and should be lowered in the tank until the commutator risers are barely covered. If the assembled winding cannot be immersed, it can be slowly rotated in a horizontal position in a shallow pan to allow the varnish to flow into the winding interstices. All winding parts should be well soaked during the immersion. At least two complete revolutions should be made, each revolution taking about 10 minutes. In the baking operation allowances

Table 2-3. –Varnishing Procedure.

Armature Coils, Armatures, Stators and Field Coils

Procedure	Processing Rebuilt Coils and Windings	
	Class A and Class B	Class H (Silicone)
(Step 1) Prebaking.	Put into oven at 110° C. (230° F.). Hold at temperature for 4 hours. Cool to approximately 50° C. (122° F.).	Put into oven at 150° C. (302° F.). Raise temperature in steps of 50° C. (122° F.) per hour to a maximum temperature of 204° C. (400° F.). Hold at temperature for 4 hours. Cool to approximately 50° C. (122° F.).
(Step 2) Dipping.	Immerse coils or wound apparatus at 40° C. (104° F.) in organic varnish, clear baking, stock number G5970-161-7232 (5-gal. cans) until bubbling ceases, Varnish should be held between 150-250 centipoises. Thin with mineral spirits, Stock No. G52-T-725-5, if necessary to maintain viscosity.	Immerse coils or wound apparatus at 40° C. (104° F.) in silicone varnish, clear baking, stock number G5970-548-7070 (5-gal. cans) or G5970-548-7208 (5-gal. cans) for not over 5 minutes. Varnishes should not be mixed. Viscosity should be held between 125-225 centipoises. Thin with xylene, stock number G6810-290-4165, if necessary to maintain viscosity.
(Step 3) Draining.	Drain and air-dry for 1 hour. Rotate wound apparatus during draining to prevent pocketing the varnish.	Drain and air-dry for 1 hour. Rotate wound apparatus during draining to prevent pocketing the varnish.
(Step 4) Cleaning.	After draining but before baking, the metal surfaces of the armature, the bore of the stator and the pole faces of the field structure should be cleaned by wiping with a cloth moistened with solvent, Stock No. G52-T-725-5.	After draining but before baking, the metal surfaces of the armature, the bore of the stator and the pole faces of the field structure should be cleaned by wiping with a cloth moistened with solvent, Stock No. G6810-290-4165.
(Step 5) Baking	Put into circulating type, forced exhaust, baking oven at temperature of 150° C. (302°F.) for 6-8 hours.	Put into circulating type, forced exhaust, baking oven at temperature of 200° C. (392° F.) for 2 hours.
(Step 6) Cooling.	Remove from oven and cool to approximately 50° C. (122° F.).	Remove from oven and cool to approximately 50° C. (122° F.).
(Step 7) Second treatment . .	Repeat steps 2 (for 1 minute immersion) 3, 4, 5, and 6.	Repeat steps 2 (for 1 minute immersion) 3, 4, 5, and 6.
(Step 8) Third treatment. . .	Repeat steps 2 (for 1 minute immersion) 3, 4, 5, and 6.	Repeat steps 2 (for 1 minute immersion) 3, 4, 5 (bake additional 8 hours at 232° C. (450°F.), and 6.

should be made for the time necessary to bring the armature up to temperature. If possible, d-c armatures should be baked with the commutator end up.

To prevent centrifugal force from throwing the coils outward, wind a band of high-grade steel piano wire on a strip of leatheroid, which is placed around the armature and over the coils about 2 inches from the edge of the core. This is done either before or after the armature has been dipped and baked.

It is preferable to place the banding wires on the armature while the windings are hot because the insulation shrinks when heated, is more flexible, and can be pulled down tightly much easier than when the armature is cold. When the first banding wire is wound on the armature, small tin clips are inserted under the wire. When the required number of turns has been applied, the ends of these clips are turned up over the wires to hold them tightly side by side. The clips are then soldered with a tin solder, and a thin coat of solder is run over the entire band to secure the wires together.

The end windings are secured, if necessary, by groups of wire wound on insulating hoods to protect the coils. On the commutator end, strips of thin mica with overlapping ends are usually placed on the commutator neck and held by a few turns of cord. On large armatures, banding wires are sometimes placed over the laminated portion of the armature. The laminations on these armatures have notches in which the banding wire is placed.

If it is necessary to rebuild a commutator, use molding micanite to insulate between the spider and the commutator. Commutator mica is used as insulation between the segments. After the commutator is assembled, it is heated and tightened with a clamping ring.

If shrink rings are provided, they are not put on until the commutator has been tightened (while hot) and the banding wires tightly placed around it. If defective, small commutators are usually completely replaced.

The completed armature (fig. 2-20) is now placed in a lathe and a very light cut taken over the surface of the commutator and over the face and side of the commutator risers to make the assembly perfectly true.

Next the commutator mica should be undercut to a depth of 1/32 to 3/64 of an inch so that the carbon brushes will not be damaged by high mica. Undercutting can be accomplished either with a motor-driven tool or a hand tool. A good hand tool for use in undercutting mica can be made from a piece of hacksaw blade mounted in a handle.

111.19
Figure 2-20.—Rewound armature.

The armature is next balanced on a pair of steel knife edges, which are perfectly level and mounted parallel to each other. Repair ships are provided with a balancing machine for armatures that require a perfect balance.

HIGH-POTENTIAL TESTS

A high-potential test is made by applying (between insulated parts) a test potential that is higher than the rated operating voltage. High-potential tests are frequently used in connection with the manufacture, repair, or reconditioning of naval equipment ashore but should not be used for routine testing aboard ship. The purpose of the test is to break down the insulation if it is weak, thereby indicating defective material and workmanship, and permitting replacement prior to actual use. Such a test, if made on apparatus installed in the ship, could result in failure requiring expensive repairs which the ship is not prepared to undertake. On the other hand, if the tests were not made, the equipment would probably continue to function satisfactorily. The application of each high-potential test tends to weaken insulation even though it does not produce actual failure at the time. Also, the use of high-potential tests requires special equipment and safety precautions, which are usually not practicable for routine shipboard use.

When making high-potential tests on electrical equipment that has been reconditioned or rewound in a shop, keep all personnel from coming in contact with any part of the circuit or apparatus. Never touch the winding after a high-potential test has been made until it has been connected to ground to remove any static charge it may have retained.

A high-potential test should not be made on a d-c generator or motor until after the reconditioning or rewinding is completed, including the application of varnish except in cases of reconditioning when the application of varnish is not considered necessary and the insulation resistance has been measured and found to be higher than the value given in the "after reconditioning in shop" column of table 2-4. This is because insulation free from defective material and workmanship that would prove to be satisfactory (if tested when clean and dry) may break down if given a high-potential test at a time when the insulation resistance is low because of dirt or moisture.

All leads to the circuit being tested should be connected to one terminal of the source of test voltage. All leads to all other circuits and all metal parts should be connected to ground. No leads are to be left unconnected for a high-potential test as this may cause an extremely severe strain, at some point of the winding. For example, to make a high-potential test on a rewound armature (fig. 2-20), short circuit the commutator segments by wrapping one or more turns of bare wire around the commutator and apply the high-potential test voltage across the common connection of all the commutator segments and the grounded armature shaft.

The high-potential test voltage is obtained from a 60-cycle, a-c source that should have a capacity of 1 kilowatt. When making a test, increase the voltage as rapidly as possible without exceeding the correct value, as indicated on the voltmeter . The full voltage should be maintained for 1 minute. The voltage should then be reduced at a rate that will bring it to one-quarter of the correct value or less in not more than 15 seconds.

The effective (rms) voltage for a high-potential test on d-c generators and motors (which have been restored to a condition that should be as good as new) with a rated voltage below 600 volts should be as follows, except for propulsion generators and motors on electric-drive battleships and equipment that has been temporarily reconditioned after submergence: Armature circuits of d-c machines—2 x E + 1,000 volts and shunt field circuits for d-c machines—2 x V + 1,000 volts, where E is the rated armature voltage and V is the rated excitation voltage.

Table 2-4.—Direct Current Generators and Motors (Except Propulsion Generators and Motors and Auxiliary Generators for Submarines).

Circuit	Insulation Resistance in Megohms at 25° C.[1]		
	Before Cleaning	After Cleaning in Vessel	After Reconditioning in Shop
Complete armature circuit[2]	0.1	0.5	1
Armature alone	0.2	1	2
Armature circuit less armature[2]	0.2	1	2
Complete shunt field circuit[2]	0.5	1.25	2.5

[1]The figures given are for machines rated at 250 volts or less. For machines having a rated voltage, E, greater than 250 volts, multiply all figures given in the table by E/250.

[2]Small machines usually have one of the shunt field leads connected internally to the armature circuit. To avoid disassembly in such cases, the complete armature circuit and complete shunt field circuit may be measured without breaking this connection. If necessary, the armature can then be isolated by lifting all brushes.

(a) With the brushes left in place, the complete armature circuit will include armature, armature circuit, and the permanently connected shunt field circuit. The values given in the table for the complete armature circuit will apply.

(b) With the brushes lifted, the armature circuit less armature and the complete shunt field circuit will be measured. The values given in the table for armature circuit less armature will apply.

CHAPTER 3

A-C WINDINGS

D-c and a-c generators both generate alternating emfs. The d-c generator utilizes a commutator to rectify the alternating voltage and supplies d-c power to the external load. The a-c generator is not equipped with a commutator and thus supplies a-c power directly to the load. It is possible to use a d-c generator as an a-c generator by placing slip rings on the shaft and connecting these rings to the proper points on the armature.

In practice, a-c machines are generally constructed with a stationary armature and a revolving field. (It will be helpful to review a-c motors and generators in Basic Electricity, NavPers 10086-A at this time.) This type of construction is preferable because (1) the armature, which usually generates a high voltage, is not subjected to the mechanical stresses due to centrifugal force when placed on a stationary structure; (2) the connection of the stationary armature to the external circuit is easily made without the use of moving contacts thus eliminating the difficulty of insulating exposed slip rings; and (3) the revolving field, which is excited through slip rings, requires a relatively low voltage that usually does not exceed 250 volts.

CHARACTERISTICS OF A-C STATOR WINDINGS

As previously stated (in chapter 2), all d-c windings are of the closed-circuit type and most a-c windings are of the open circuit type. In the open-circuit type of winding there is a continuous path through the armature but the winding does not reenter itself.

The same general principles apply to a-c windings that apply to d-c windings. The span of each coil must be such that the two sides occupy positions under poles of opposite polarity. The coils must be connected so that the generated emfs add together in the series circuit.

The distance between the two sides of a coil is the COIL PITCH. When the coil spans exactly the distance between the centers of adjacent poles, called the POLE PITCH (180 electrical degrees), the coil and winding are FULL PITCH. Under this condition the generated voltages in both coil sides are exactly in phase. On the other hand, if the span of the coil is less than one pole pitch, the coil and winding are FRACTIONAL PITCH. Fractional-pitch windings are more generally used than full-pitch windings because their generated voltage can be made to more nearly approximate a sine wave. However, when fractional-pitch windings are used, the generated voltages in the two sides of a coil are not in phase with each other, and the resultant coil voltage is less than it would be for a full-pitch winding. The ratio of the voltage generated in the fractional-pitch coil to the voltage generated in the full-pitch coil is the PITCH FACTOR (chord factor). Allowance must be made for the reduction in voltage by use of a chord factor which is expressed as

$$\text{chord factor} = \sin 1/2 \text{ (coil span in electrical degrees)}$$

The coil pitch is expressed as a percent of full pitch. Thus, if the pole pitch or full pitch is 10 slots on the stator core and the coil pitch is 8 slots, the winding is approximately 0.8 pitch, which is equivalent to 0.8 x 180, or 144 electrical degrees.

A CONCENTRATED WINDING occupies only one slot per pole. A PARTIALLY DISTRIBUTED WINDING occupies more than one slot per pole but does not utilize the entire surface of the stator. A FULLY DISTRIBUTED WINDING occupies all the slots, which are uniformly spaced over the entire surface of the stator core.

A-c windings, similar to d-c windings, can be either single layer or two layer. Irrespective of the number of turns per coil, a single-layer

winding has only one coil side per slot; whereas, a two-layer winding has two coil sides or two winding spaces per slot.

When a winding has one-half as many coils as slots, it is called a single-layer, or half-coil (basket) winding. When a winding has the same number of coils as slots, it is called a two layer, or whole-coil, winding.

CLASSIFICATION

The general classes of a-c stator windings are the (1) lap, (2) wave, and (3) spiral windings (fig. 3-1). Single-phase windings, and only one turn per coil, are shown for simplicity.

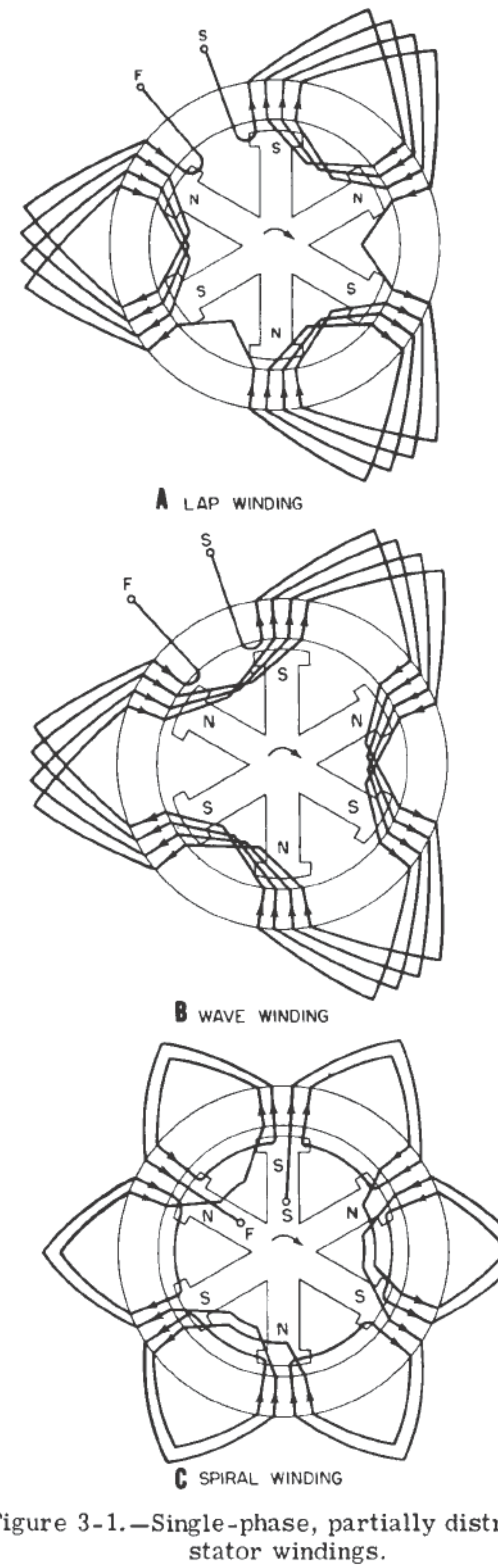
The wave winding in the d-c armature for a given total number of armature conductors has a larger number of series conductors (fewer parallel paths) and generates a higher voltage than the lap winding under the same conditions.

The wave winding in the a-c armature for a given total number of armature conductors has the same number of series conductors and generates the same voltage as the lap winding under the same conditions.

The condition is verified by comparing the same armature connected as a lap and wave winding (fig. 3-1A and B) respectively. The windings are for a 6-pole, partially distributed winding with 4 slots per pole. Hence, the wave winding has no advantage over the lap winding in the generation of a high voltage. Also, the length of the end connections between coils is shorter in the lap winding.

The same armature connected as a spiral winding for a 6-pole, partially distributed winding with 4 slots per pole is illustrated in figure 3-1C. Each coil group is connected in the form of a spiral and employs two different shapes of coils with different pitches. The winding has fewer crossings of the end connection but has the disadvantage of requiring several different shapes of coils, the number increasing with an increase in the number of slots per pole. For example, a spiral winding with 6 slots per pole requires coils of three different shapes, and so on. The spiral-wound armature is always a single-layer winding; whereas, the lap and wave windings are usually two layer.

The lap and wave windings (fig. 3-1A and B) are full pitch because each coil spans 180 electrical degrees. The spiral winding (fig. 3-1C) is not full pitch but the voltage induced in any two adjacent coil groups is the same (under the same conditions) as the voltage induced in any



111.60

Figure 3-1.—Single-phase, partially distributed stator windings.

one coil group of the lap and wave windings. Hence, the spiral winding is equivalent to a full-pitch winding.

A single-phase winding has all the coils connected so that the winding terminates in two free ends. A single-phase machine consists of one winding, the coils of which occupy slots on the stator that are one pole pitch apart (180 electrical degrees). A polyphase winding consists of two or more single-phase windings symmetrically spaced on the armature. Thus, a 2-phase machine has two single-phase windings spaced 90 electrical degrees apart. A 3-phase machine has three single-phase windings spaced 120 electrical degrees apart. Three-phase stator windings are usually connected in wye or delta. Single-phase windings are seldom used as such, except in the stators of small motors.

LAP WINDINGS

The type of winding that is most extensively used in a-c stators is the two-layer, distributed lap winding, which is very similar to the d-c lap winding. The two general arrangements of the 3-phase stator windings are the (1) half-coil and (2) whole-coil windings.

Half Coil Winding

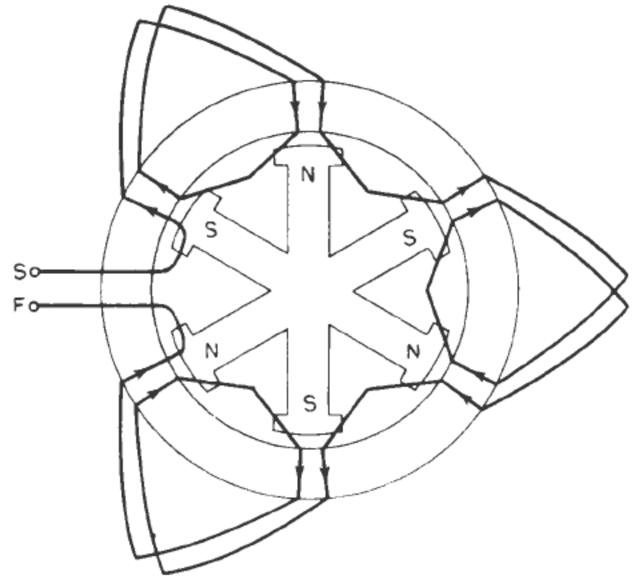
A schematic diagram of one phase of a 3-phase, half-coil lap winding for a 6-pole machine is illustrated in figure 3-2. There are three groups of coils ($\frac{P}{2}$ groups) with two coils in each group.

Whole Coil Winding

A schematic diagram of one phase of a 3-phase, whole-coil lap winding for a 6-pole machine is illustrated in figure 3-3. There are six groups of coils (P groups) with two coils in each group. The successive groups carry currents in opposite directions over poles of opposite polarity. Note that there are two coil sides in each slot compared with one coil side per slot in the half-coil winding (fig. 3-2). The whole-coil winding is more commonly used than the half-coil winding and is very similar to the two-layer, d-c lap winding.

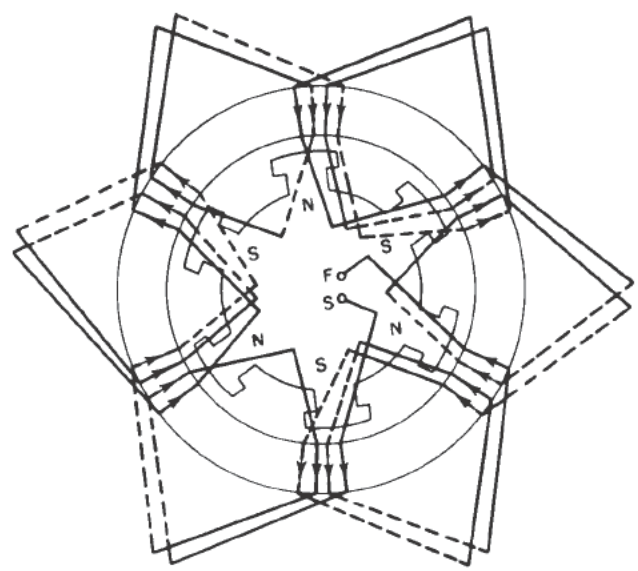
POLE-PHASE GROUPS

The total number of coils that comprise an a-c winding are divided into pole-phase groups.



111.61
Figure 3-2.—One phase of 3-phase, half-coil, 6-pole lap winding.

There are as many pole-phase groups in a winding as there are poles times the phases. If a winding is to be connected for 6 poles, each phase must be connected so that its coils produce 6 magnetic poles or has 6 groups of coils. Thus,



111.62
Figure 3-3.—One phase of 3-phase, whole-coil 6-pole lap winding.

for a 3-phase winding there must be 6 groups for each phase or a total of 18 pole-phase groups.

A pole-phase group consists of two or more coils, which are always connected in series. They are never connected in parallel because the voltages are out of phase due to the distribution factor, and circulating currents would flow between the coils and damage the winding. The number of coils to be connected in series for each group is determined by the total number of coils in the winding and the number of pole-phase groups. The number of coils per pole-phase group is the total number of coils divided by the number of pole-phase groups. For example, for a 3-phase, 6-pole, 36-coil winding, the number of pole-phase groups is 6 x 3, or 18, and the number of coils per group is 36 ÷ 18, or 2.

The coils in each pole-phase group are adjacent and always connected in series, the finish of one coil being connected to the start end of the next adjacent coil. The process of connecting these coils in pole-phase groups around the stator is known as STUBBING.

Unequal coil groups result when the number of coils in each group varies. For example, in a 6-pole, 48-coil, 3-phase series winding, the total number of groups is 6 poles times 3 phases, or 18 groups. The number of coils per group is 48 coils divided by 18 groups, or $2\frac{12}{18}$. Because of the fraction, it will be necessary for some groups to have three coils and some to have two coils. Numerator 12 of fraction $\frac{12}{18}$ determines the number of groups with the larger number of coils. Hence, 12 groups will have 3 coils (36 coils), and the remaining 6 groups will have 2 coils (12 coils), giving a total of 48 coils.

After the number of coils per groups is determined, the groups must be placed so that each phase has the same total number of coils. This is accomplished by laying out the groups with three coils in all groups and then subtracting one coil from each of the 6 groups, as

ABC	ABC	ABC	ABC	ABC	ABC
333	333	333	333	333	333
1	1	1	1	1	1
233	332	323	233	332	323

Be certain to subtract an equal number from each phase. Also ascertain that there is an equal number of coils in each phase, and that the groups are distributed symmetrically.

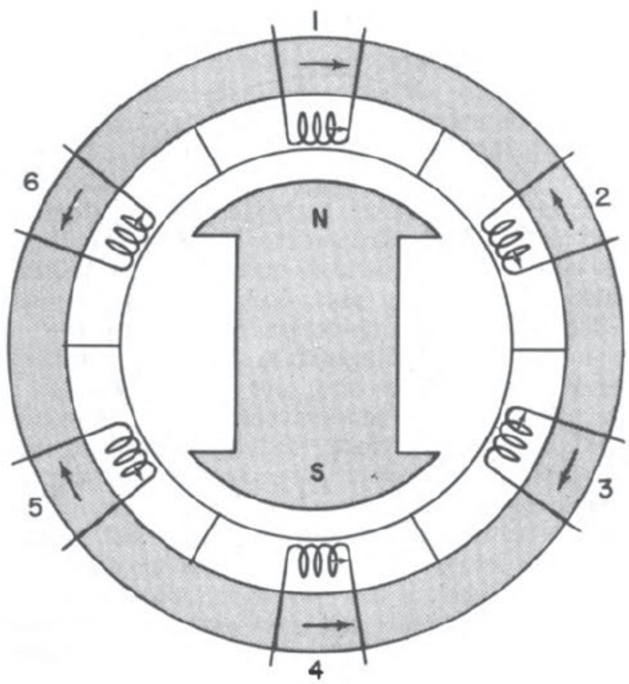
In parallel-connected windings all parallel paths must contain the same number of coils. As stators with the same number of slots may be used for motors having a different number of poles, phases, or parallel paths, some windings require dummy coils. If the total number of coils divided by the total number of paths leaves a numerical remainder, the remainder is the number of unused or dummy coils. The dummy coils are separated from each other with equal (or near-equal) intervals. Their ends are taped to remain opencircuited.

Polarity of Pole-Phase Groups

The winding diagrams of polyphase stators indicate the number of pole-phase groups in the winding, the instantaneous relative polarities of the pole-phase groups, and the interconnection of the groups and phases. The total number of coils is not shown (only the groups of coils), thereby simplifying the diagram to apply to any stator connection that has the same number of phases, same number of poles, and same method of interconnections, irrespective of the number of coils per group.

The instantaneous polarities of the pole-phase groups are required to determine the correct method of interconnecting the groups in each phase. If the groups per phase are to be connected in series, the connections must be made so that the voltages of the several groups add together, and, if the groups per phase are to be connected in parallel, the connections must be made so that short circuits do not exist because of incorrect connections.

For example, the relative polarities of a 3-phase, 2-pole alternator winding can be determined by constructing a simple diagram of the number of pole-phase groups and the number of poles in the rotor (fig. 3-4). If the field is assumed to be rotating past pole-phase groups 1 and 4 in the clockwise direction, the direction of the induced voltage in group 1 can be chosen arbitrarily. The direction of the induced voltage in the remaining coils must then be designated with respect to that of group 1. At the same instant that the north pole is passing group 1, the south pole is passing group 4 in the same direction. The direction of induced voltage in group 4 must be opposite that in group 1 because



111.63
Figure 3-4.—Pole-phase groups of 3-phase, 2-pole alternator.

the polarity of the magnetic field cutting the conductors is opposite to that of group 1. The direction of induced voltage is indicated by the arrows (fig. 3-4).

When the rotor is turned 120° clockwise to the next phase, the north pole will be passing group 3 and the direction of induced voltage must be the same as that for group 1. At the same time, the south pole will be passing group 6, and the direction of induced voltage must be the same as group 4. When the rotor is turned another 120° clockwise to the third phase, the north pole will be passing group 5, and the direction of induced voltage will be the same as that of groups 1 and 3. At the same time, the south pole will be passing group 2, and the direction of induced voltage will be the same as that of groups 4 and 6.

The arrows indicate the relative directions of the voltage in the groups of each phase and assume the phases to be displaced by 120°, as required for any 3-phase winding. The same analysis can be conducted for an alternator or motor having any number of poles. The polarities can be indicated by assuming a direction in any one group and following the rule that the polarity of each adjacent group is reversed.

Interconnection of Pole-Phase Groups

The connection of the pole-phase groups in each phase as series, parallel, or series-parallel is determined by the manufacturer in order to meet specific horsepower, capacity, voltage, and other specifications for the machine (fig. 3-5). In reconnecting a winding, the Electrician's Mate must consider the method of group connections for a given voltage before making any changes. Connecting the groups in series (fig. 3-5A) doubles the operating voltage required if the groups were originally connected in parallel. If it is necessary to reduce the operating voltage required by a machine to one-half, reconnect half the group in each phase in parallel with the other half.

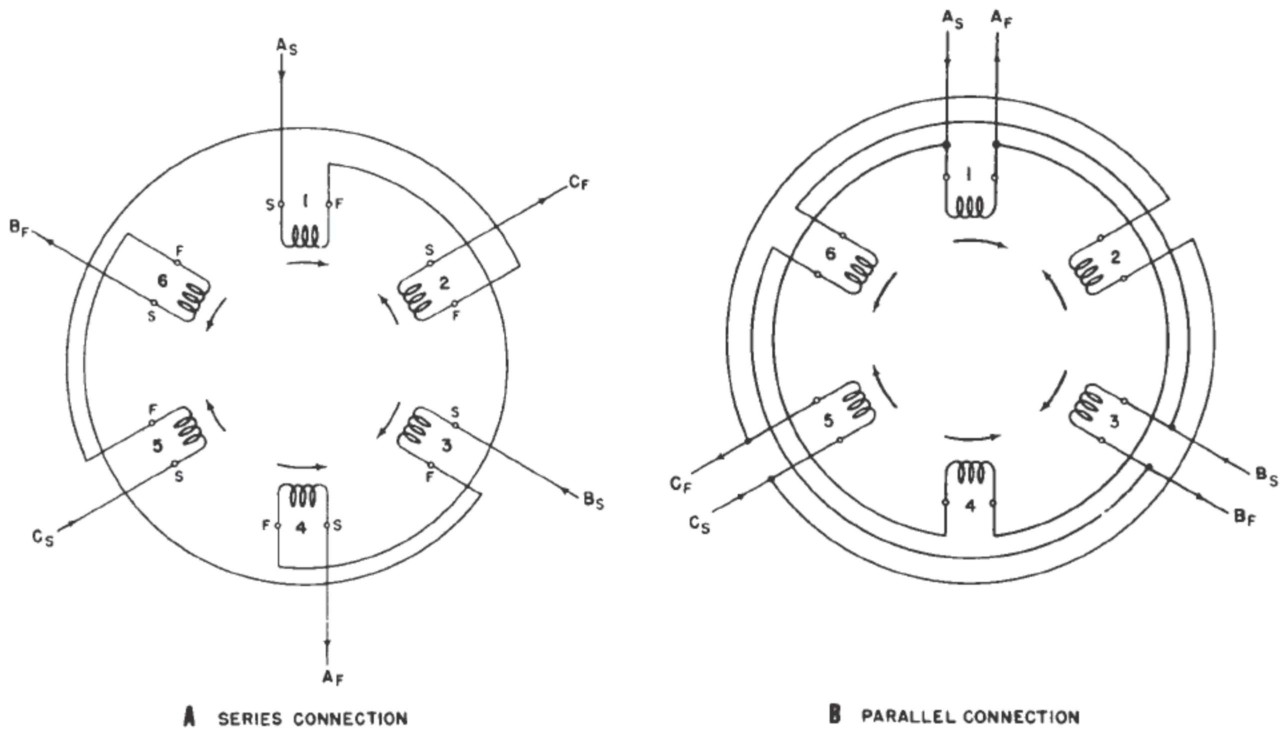
If there are four groups originally in series in each phase, the groups can be reconnected as four groups in parallel, thereby reducing the operating voltage required to one-fourth the original value. Also, the same four groups can be reconnected as two parallel groups (two groups in series, paralleled with the other two groups in series), thereby reducing the operating voltage one-half.

Note that the polarities of the groups connected in series (fig. 3-5A) are additive, which requires reversed connections of the pole-phase groups. In other words the finish ends, F, of each group are connected together instead of connecting the start end, S, to the finish end, F, of each as would seem appropriate. Thus, the connections of successive groups in any phase must be reversed in order for the voltages to add together.

INTERCONNECTION OF PHASES

Three-phase stator windings are ordinarily connected in wye or delta. A wye-connected stator winding may have the FINISH of each phase connected together and the START of each phase forms the line leads or vice versa. A delta-connected stator winding has the start of each phase connected to the finish of the next phase, and the line leads are connected to each of these three points.

The relation between the values of phase and line voltage and current are different for the wye- and delta-connected windings. In the wye-connected winding the line voltage is equal to $\sqrt{3}$ times the phase voltage ($E=\sqrt{3} \times e$); and



111.64
Figure 3-5.—Interconnection of pole-phase groups in 3-phase, 2-pole alternator.

the line current is equal to the phase current (I = i). In the delta-connected winding the line voltage is equal to the phase voltage (E = e); and the line current is equal to $\sqrt{3}$ times the phase current ($I = \sqrt{3} \times i$). The square root of 3 is 1.732.

With equal phase windings, the voltage is smaller between the line leads in a delta-connected winding, but the possible current output is proportionately greater. However, for both delta and wye windings the apparent power capacity per phase is e x i. The two basic types of phase connections have equal power capacity. The total apparent power of all three phases together is $P = \sqrt{3}\ EI$. These connections are described in detail under 3-phase winding connections later in this chapter.

STATOR REWINDING

When laying out a new winding or reconnecting an existing winding, the number of stator slots, the operating voltage, the speed, the number of phases, and the frequency must be considered. The number of slots determine the total number of coils in the winding, and there are as many coils as there are slots in the two-layer, whole-coil winding.

In the a-c generator, the stator must be wound for as many poles as there are poles in the field winding. In the a-c motor, as in the a-c generator, the number of poles for which the stator must be wound is determined by the frequency and the speed at which the motor is to operate. The operating voltage determines the number of turns per coil, the method of interconnecting the pole-phase groups, and the choice of the phase connections.

Tests

As in d-c armatures, the most common troubles encountered in a-c stators are grounds, opens, and shorts. The methods of locating and detecting these faults in a-c machines are described in Chapter 5 of the Navy training course, Electrician's Mate 3 and 2, NavPers 10546.

If tests on an a-c generator or motor indicate that the stator winding is defective and requires rewinding, the same general procedure must be

followed that applies to rewinding a d-c armature. All available information concerning the machine should be reviewed prior to starting the work. This includes reviewing the material history card (NavShips 527A), the resistance test card (NavShips 531), the master drawings, and the technical manuals.

It is most important to keep an accurate record of all the pertinent data concerning the winding on the stator data sheet, as shown in figure 3-6. If possible this information should be obtained before stripping; if not, it can be obtained during the stripping operation.

To determine the type of connection it is necessary to understand the various types of connections described later in this chapter. Ordinarily, no change in the design or winding of a machine is permitted, and an exact reproduction of the original wiring is sufficient. However, if a change in voltage or speed of a machine is considered necessary and a redesign of the winding is authorized, the Electrician's Mate should prepare new diagrams in advance of the actual repair. Another competent Electrician's Mate or Warrant Electrician in charge should check and approve the diagrams before the winding is begun.

Stripping

An a-c stator is stripped in the same manner as a d-c armature. Exercise care to preserve one coil in the original shape to provide the dimensions for the new coils if spare coils are not available and it is necessary to rewind them. Be certain to measure the end room of the coils before they are removed from the slots. Record this distance on the data sheet and be sure that the new coils do not extend beyond this distance from the ends of the slots. The winding should be preheated in an oven to soften the varnish and thus facilitate stripping. The end connections, preferably at the lead end, are then cut and the coils removed from the slots by pliers or a screw driver.

After the stator is stripped inspect the laminations for alignment burs, especially sharp burs protruding from the end laminations. The stator should be cleaned of all dirt, grease, rust, and scale. The stator, similar to the d-c armature, is then varnish dipped and baked, using a dilute varnish of the same type that is used after winding. This treatment prevents the formation of oxides and forms a base for adherence of the final varnish treatment.

Make

H.P.	R.P.M.	Volts	Amps.
Cycle	Type	Frame	Style
Temp.	Model	Serial	Phase

No. of Coils	No. of Slots	Connection
Size Wire	No. of Turns	No. of Groups
Coils/Group	No. of Poles	Pitch of Coil

111.65

Figure 3-6.—Stator data sheet.

WINDING OF STATOR COILS

The rewinding of class A and class B insulated a-c generators and motors should be accomplished with the same materials shown on the master drawing. For small and medium size machines the coils can be wound by hand (mush coils) in the stator slots, but for large machines over 100 h-p they are usually prewound and preformed (formed coils). The size and shape of the coils are best determined from the coil that was removed from the stator intact. With this coil as a model, use a winding board, or form, to duplicate exactly the shape of the winding. For small machines, the coils can be wound in rectangular forms and then stretched to the desired shape by pulling at the centers of opposite sides.

When the coil is wound, tie it in several places to hold the turns together and remove it from the form. The two wires forming the leads are taped or sleeved with glass braided sleeving. The excess insulation is removed from the free ends of each coil, which are then tinned. The individual coils are then checked electrically for continuity and for shorted turns.

PLACING COILS IN SLOTS

The ground insulation, consisting of flexible mica wrappers or layers of reinforced mica tape, is applied to the coil sides that lie in the

stator slots. The coils to be inserted in semi-enclosed slots have only the ends taped to facilitate spreading of the coil sides. The turns of the coil side are spread out and the coil is held at an angle so that all the turns can be fed into the slot. Be certain that each turn is placed inside the ground insulation. A ground will result if the coil sides are placed mistakenly between the insulation and the core. Pull the side of the coil through the slot until all the turns are in the slot.

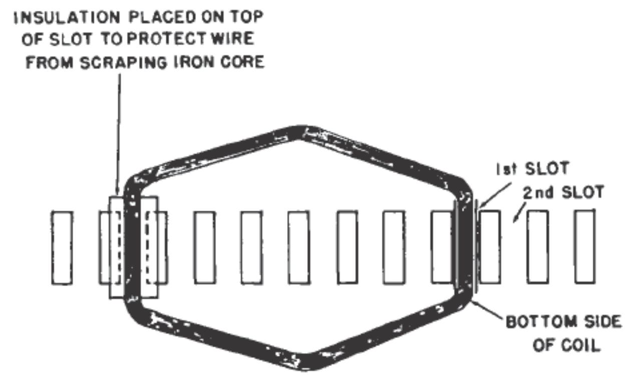
The coils to be inserted in open slots have the entire surface taped, and the coil sides are placed in each slot intact. The right side of the coil, which occupies the bottom half of the slot, is inserted first (fig. 3-7). The free end coming from this side is known as the bottom lead of the coil. The left side of the coil, which occupies the top half of another slot, remains free. Continue by placing the right side of the second coil in slot 2 adjacent to slot 1. The remaining coils are inserted in this manner until the slots spanned by a complete coil pitch each contain the right side of a coil. The left side of each coil remains out of the slot until the bottom half of the slot is occupied by the right side of a coil. Continue around the stator, and then insert the left side of each coil on top of the right side of a coil several slots away, depending on the coil pitch.

Before inserting the side of the second coil in a slot, insulate it from the first coil's side already in the slot. This is done by placing a strip of insulation over the bottom coil.

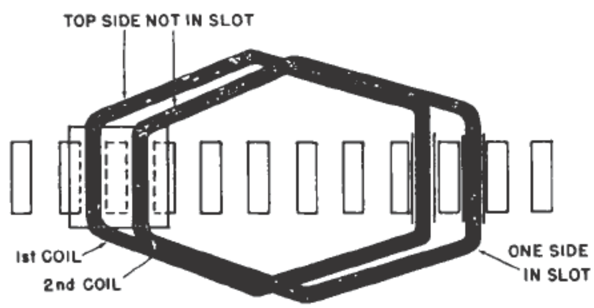
Be certain that each coil side extends beyond the slot at both ends and does not press against the stator core at the corners. The phase insulation consisting of varnished cambric is placed between the phase groups because of the high voltage existing between phases. The computations indicated under interconnection of phases should be completed before any coils are inserted in the stator to allow for this extra insultation.

After the stator coils are all in place, force the coil sides down in the slots by placing a piece of soft wood or fiber on top of the coils through the slot opening, and gently tapping on it. When the coils are securely in the slots, insert the slot wedges to hold the coils in place. The wedges consist of flat melamine laminates machined to shape.

When all the coils have been inserted in the stator slots, the ends insulated, and the slot wedges driven in place, there will be two free



FIRST COIL OF WINDING IN PLACE



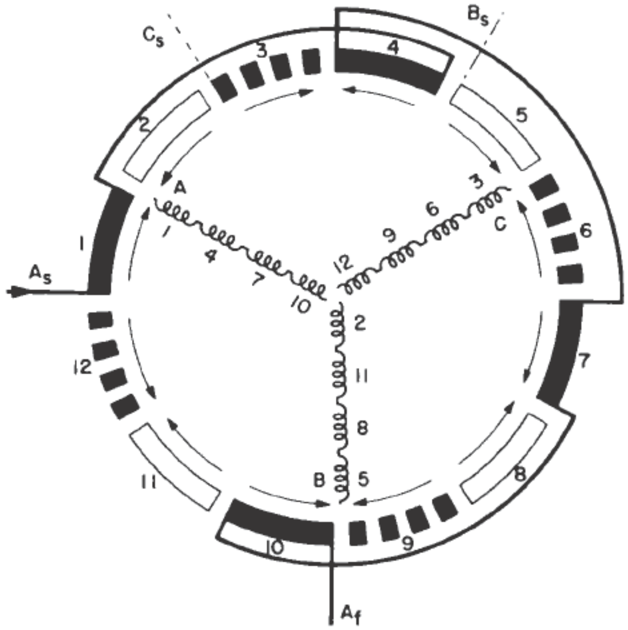
SECOND COIL OF WINDING IN PLACE

111.66

Figure 3-7.—Placing coil sides in slots.

ends for each coil (top and bottom) extending from one side of the stator winding. The free ends must be connected to form a series of groups of coils. The number of coils connected in any one group depends on the total number of coils used, the number of phases, and the speed of the machine. For example, in a machine that has 36 stator slots and 36 coils (fig. 3-8), the winding is arranged for three phases and four poles. If the four poles are formed in each phase, there must be 3 x 4, or 12 pole-phase groups. Because there are 12 pole-phase groups, it follows that there are 36 ÷ 12, or 3 coils, in series in each group. Therefore, it is necessary to connect three consecutive coils together in series for each pole-phase group.

In arranging these coils into pole-phase groups, start by bending (forming) the inside lead



111.67
Figure 3-8.—Three-phase, 4-pole winding for 36-slot (and coil) stator.

of the first coil in toward the center and then bend the outside lead of that coil and the inside lead of the next coil together. Connect the outside lead of the last coil with the inside lead of the next coil and bend the outside lead of this coil away from the center. Repeat this procedure for each of the pole-phase groups all around the stator. Do not solder the connections at this time.

After twisting the ends together, check the individual groups to determine that the proper number of coils have been connected together in each pole-phase group and that they have the proper polarity. Then solder the twisted connections and cut off the ends so that the soldered stubs are about three quarters of an inch long. Insulate the stubs with cotton tape or reinforced mica tape.

If the distance to the bearing brackets (frame of the machine) is small, bend the insulated stub in between the coils so that they do not come in contact with the frame when the stator is assembled in the machine.

In practice, the coils that comprise the pole-phase groups are usually gang wound. Gang wound coils eliminate the need for stubbing because the coils are wound with a continuous length of wire.

CONNECTIONS OF WINDINGS

Having connected the coils together in series for each pole-phase group, the next step is to connect the different pole-phase groups together. The groups of coils of one phase can be connected so that all the groups are in series, in parallel, or in a combination of series and parallel groups, depending on the number of pole phase groups in the machine and the required voltage and current. The phases are then arranged in a wye or delta connection.

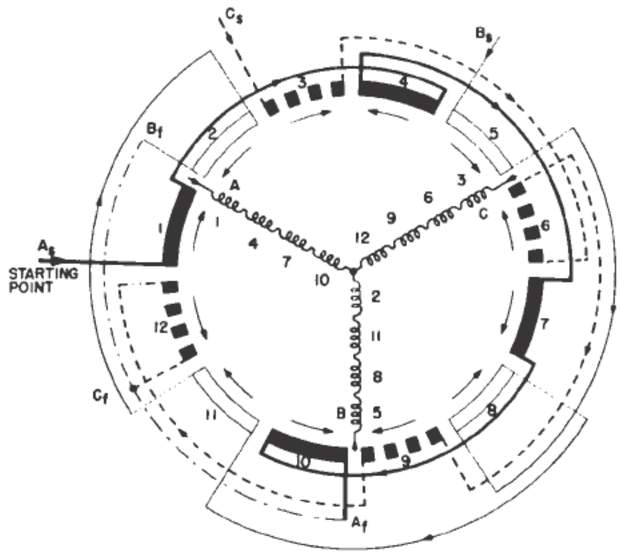
Before connecting the pole-phase groups together construct a diagram containing the pole-phase groups in each phase and the number of poles for the particular machine, as illustrated in figure 3-8. Be certain that the pole-phase groups for each phase are connected properly to produce alternate north and south poles by indicating the direction of current flow through each pole-phase group by arrows that must reverse direction for each successive group.

SERIES-WYE WINDING

To connect the machine under consideration (fig. 3-8) for 3-phase, 4-pole, series-wye operation, connect the pole-phase groups into phase groups. The pole-phase groups of the A phase must be connected in series so that the current flows through the first A group (group 1) in the direction of its associated arrow and through the second A group (group 4) in the direction of its arrow, which is opposite to the direction of group 1. This procedure is followed for the remaining pole-phase groups to produce alternate north and south poles. Bring out the start end of group 1 for the external connection of phase A and then connect the finish end of phase A to the finish ends of phases B and C (fig. 3-9). Note that the alternate arrows provide a guide for the proper connection of the pole-phase groups.

Next connect the pole-phase groups of phase C exactly as described for phase A, beginning with the start end of pole-phase group 3, which is brought out for the external connection of phase C. Note that one pole-phase group (group 2) belonging to phase B is passed over (skip group method) in order to begin with pole-phase group 3 as the start of phase C.

Now connect phase B in the same manner as phases A and C by bringing out the start end of pole-phase group 5 for the external connection of phase B. Note that the start of phase B begins



111.68
Figure 3-9.—Three-phase, 4-pole, series-wye winding.

at pole-phase group 5 instead of pole-phase group 2.

The reason for passing over pole-phase group 2 of phase B in order to begin with pole-phase group 3 of phase C in the sequence of connecting the phases is to make the connections for all three phases alike and to maintain the indicated polarities of the groups.

The associated arrow under each pole-phase group indicates the assumed direction of current flow. The polarity indications facilitate checking the connections for the correct polarity of adjoining pole-phase groups.

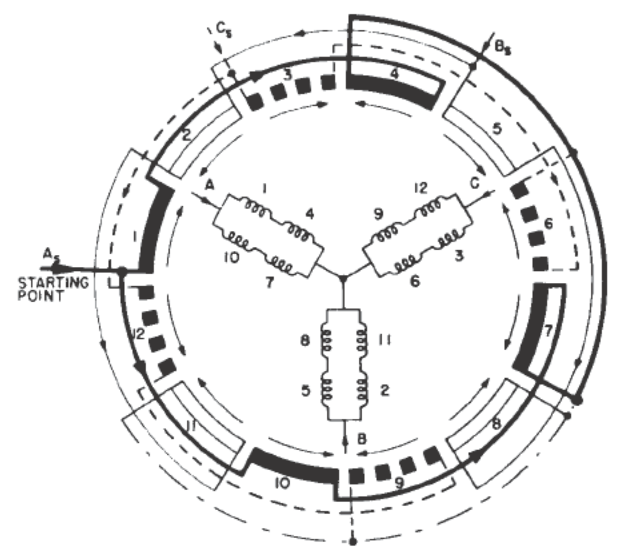
All the arrows on the line leads (fig. 3-9) indicate current in the same direction toward the center of the wye. Actually, the current at one instant may enter the phase A lead and leave by the other two leads. At the next instant current may enter through phases A and B and leave by phase C. At any instant, current is flowing into and leaving, the wye by at least one lead.

The principal considerations in constructing a correct 3-phase diagram (fig. 3-8) is to alternate the direction of current flow on adjacent pole-phase groups and to skip the second pole-phase group in the first pole when connecting the phase groups. This procedure provides a check for the correct connections of 3-phase windings.

The series-wye connection (fig. 3-9) is employed in a-c machines designed to operate at a comparatively high voltage. Machines that require a relatively high current usually are wound in a multiple or parallel arrangement.

PARALLEL-WYE WINDING

To connect the machine under consideration for 3-phase, 4-pole, parallel-wye operation, use the diagram shown in figure 3-8 with the same number of pole-phase groups and the same assumed directions of current flow through the groups. As in the series-wye connection, the pole-phase groups of the three phases must be connected so that the current flows through the various groups in the directions indicated to obtain alternate north and south poles. Accordingly, in phase A (fig. 3-10) connect pole-phase groups 1 and 4 in series and groups 10 and 7 in series and connect these groups in parallel. Bring out the start of groups 1 and 10 for the external connection of phase A and then connect the finish of groups 4 and 7 of phase A to the finish of phases B and C. Note, that the start of phase A is split into two paths (each path having two pole-phase groups in series) and that the two paths terminate at the finish of phase A.



111.69
Figure 3-10.—Three-phase, 4-pole, parallel-wye winding.

Next connect the pole-phase groups of phase C exactly as described for phase A, passing over pole-phase group 2 of phase B. Bring out the start of pole-phase groups 3 and 12 for the external connection of phase C.

Now connect phase B in the same way as phases A and C by bringing out the start ends of pole-phase groups 5 and 2 for the external connection of phase B.

The only difference between the parallel-wye winding (fig. 3-10) and the series-wye winding (fig. 3-9) is that the four pole-phase groups, which were originally in series in any one of the phases, are now split into two parallel groups of two each. In phase A the same coil groups are used, but the series group 1 and 4 is placed in parallel with the series group 10 and 7, resulting in an increase in the current-carrying capacity and a corresponding decrease in voltage of that phase without changing the number of pole-phase groups or without changing the groups themselves.

SERIES-DELTA WINDING

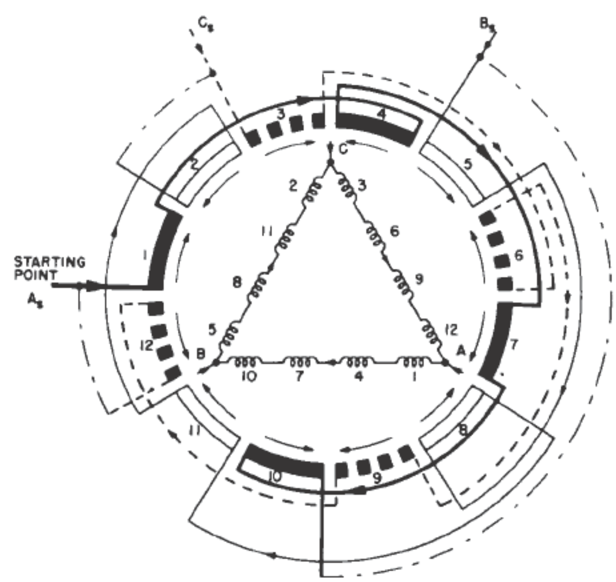
The same machine connected for 3-phase, 4-pole, series-delta operation is illustrated in figure 3-11. The same pole-phase group numbers are allotted to the same phase windings and the directions of current flow through the groups are the same as for the other examples.

The start of phase A, pole-phase group 1, is connected to the finish of phase C, pole-phase group 12; the start of phase C, pole-phase group 3, is connected to the finish of phase B, pole-phase group 2; and the start of phase B, pole-phase group 5, is connected to the finish of phase A, pole-phase group 10. As in the previous examples, pole-phase group 2 of phase B is passed over in order to maintain reversed polarities of adjoining pole-phase groups. The external connections for the three phases are brought out at the junction of each phase.

Note the difference in the series-wye winding (fig. 3-9) and the series-delta winding (fig. 3-11). In the series-delta winding the three phases are connected so that they form a delta, and the external connections are made at the three corners of the delta.

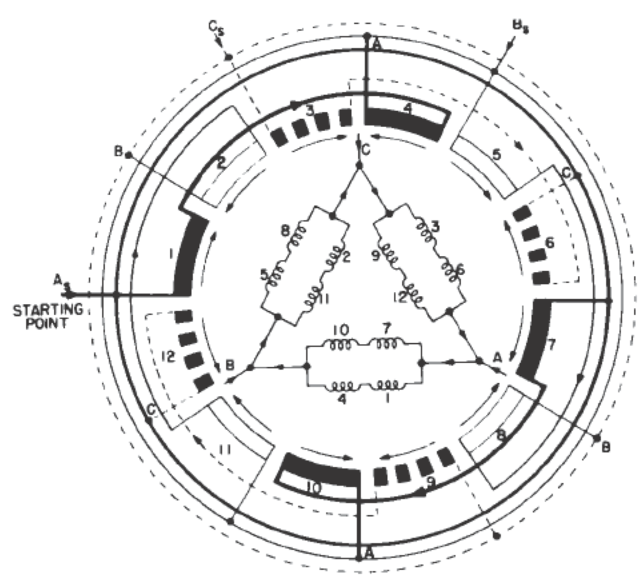
PARALLEL-DELTA WINDING

The machine used in the other examples, connected for 3-phase, 4-pole, parallel-delta operation, is illustrated in figure 3-12. The phase windings contain the same pole-phase



111.70

Figure 3-11.—Three-phase, 4-pole, series-delta winding.



111.71

Figure 3-12.—Three-phase, 4-pole, parallel-delta winding.

group numbers, and the polarities of the pole-phase groups are the same as in the previous cases. The same procedure is used in connecting the pole-phase groups into parallel paths as that used in the explanation of the parallel-wye winding (fig. 3-10).

MULTISPEED WINDINGS

The synchronous speed of the a-c revolving field of an induction motor depends on the frequency of the supply and on the number of poles. The only methods of varying the synchronous speed is to change either or both of these factors. To change the frequency requires frequency changers, but to alter the number of poles requires only a control panel. The pole-changing method provides definite speeds, which correspond to the number of poles selected.

Multispeed motors are used throughout the Navy in preference to slip ring induction motors when the speeds available from these motors meet the particular requirements. There are several reasons for this preference but the most important are those concerning maintenance. Multispeed motors have no brushes and are operated by small controllers with the result that the upkeep is practically negligible compared with slipring motors.

Multispeed motors are of the single- or two-winding types. The single-winding type has stator windings that can be reconnected externally to change the number of poles and thus obtain either one of two speeds having a ratio of 2 to 1.

The two winding type has two separate stator windings, each of which is wound for a different number of poles so that two separate synchronous speeds can be obtained by connecting the supply to one or the other winding. The windings are placed in the stator slots one above the other and are electrically insulated from each other. The supply to the terminals is usually interlocked mechanically so that only one winding can be energized at any one time. Any of the a-c windings described in this chapter can be used in a two-winding multispeed motor to obtain two definite synchronous speeds. For example, an 8-pole, series-delta winding can be placed in the stator slots over a 4-pole, parallel-wye winding to produce two synchronous speeds.

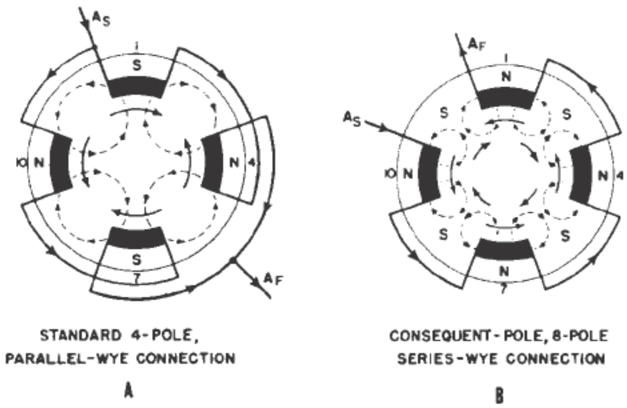
The stator windings of the two-winding motor can also be arranged to alter the number of poles as in the single-winding type to give two speeds for each winding, but the two speeds obtained on a single winding must have a 2 to 1 ratio. For example, one winding can be connected for either 4 or 8 poles, and the other winding can be connected for either 6 or 12 poles. Thus, the synchronous speeds for such a motor (60 cycle) would be 1800, 900, 1200, and 600 rpm.

In the usual 3-phase, 4-pole winding, the successive pole-phase groups of each phase are connected so that they always produce poles of opposite polarity (fig. 3-9). However, if all the pole-phase groups of each phase are connected so that their polarities are always the same at any instant, then by consequence, four additional poles of the opposite polarity will be produced at the same instant. In other words, by connecting all the pole-phase groups for the same polarity in a whole-coil winding, the stator acts as though there are twice as many poles as there are pole-phase groups. The additional poles thus established are called consequent poles, and the winding is a CONSEQUENT POLE WINDING.

The short jumper connection has been used to connect the previously described phase windings. Short jumper connections are made by connecting the end of a pole-phase group to the end of the following pole-phase group of the same phase. These connections are also known as top-to-top connections.

The long jumper connection is generally used to connect the pole-phase groups in two-speed motors because a much simpler controller can be utilized for changing the connections of the pole-phase groups. Long jumper connections are made by connecting the end of the first pole-phase group to the beginning of the third pole-phase group of the same phase. These connections are known as top-to-bottom connections.

One phase (phase A) of a 3-phase, two-speed, stator winding of a consequent-pole motor is illustrated in figure 3-13. The winding is arranged so that the external connections to the pole-phase groups can be changed by means of a controller to alter the number of poles in the winding. When the controller is operated to the HIGH SPEED position, the pole-phase groups are connected for the standard 4-pole, parallel-wye connection (fig. 3-13A). When the controller is operated to the LOW SPEED position, the pole-phase groups are connected for the consequent-pole, 8-pole, series-wye connection.



111.72
Figure 3-13.—One phase of a 3-phase, consequent-pole winding.

When the connections of a stator are changed to produce 8 instead of 4 poles, the pole width changes and therefore the chord (pitch) factor also changes. In other words, a stator connected for full-pitch for the high number of poles is half pitch for the low number of poles. This pitch usually produces the best torque and flux conditions. When the pitch is greater than 80 percent for the low number of poles (salient-pole connections), little or no power is developed for the high number of poles (consequent-pole connections).

Consequent-pole motors are designed to give different operating characteristics and are grouped into the (1) constant-horsepower, (2) constant-torque, and (3) variable-torque, variable-horsepower types.

In the CONSTANT HORSEPOWER motor the torque varies inversely as the speed. The low-speed connection allows more current to flow, thereby increasing the torque. As the torque is increased in the same ratio that the speed decreases, the horsepower remains unchanged. This relation is expressed by the equation

$$hp = \frac{TN}{5252}$$

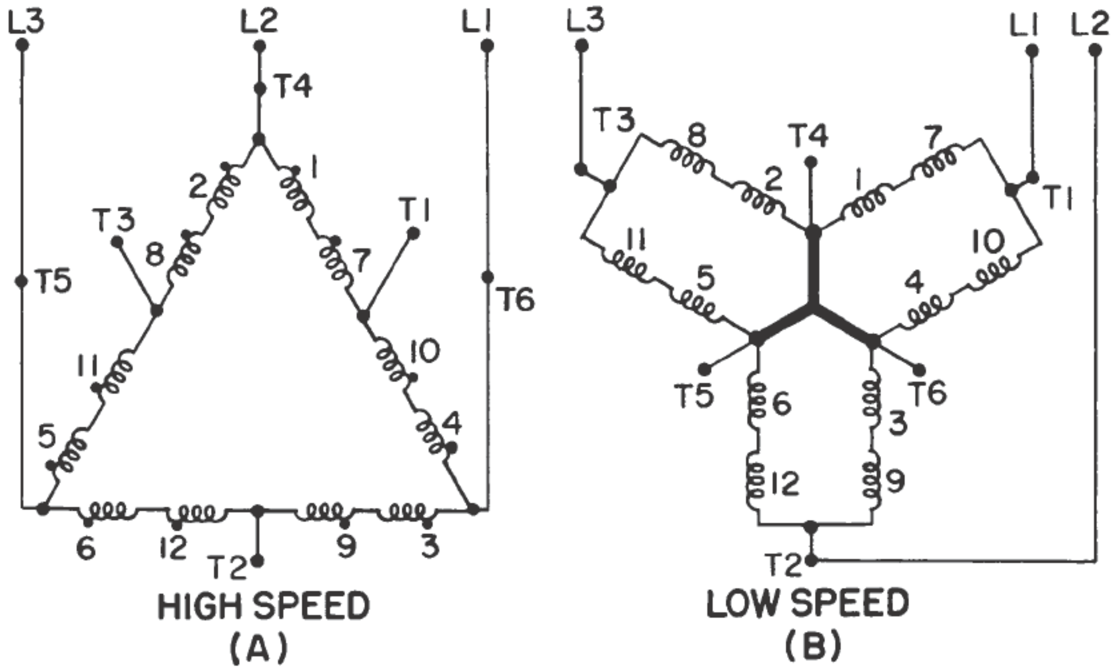
where T is the torque in pound-feet and N is the speed in rpm.

The connections of the phases in a constant-horsepower, 2-speed motor are illustrated in figure 3-14. Six leads are brought out from the winding. When the controller is operated to the HIGH SPEED position (fig. 3-14A), the stator leads T6, T5, and T4 are connected to the power lines L1, L2, and L3 while the stator leads T1, T2, and T3 are disconnected. This action of the controller connects the pole-phase groups for the standard 4-pole, series-delta connection. When the controller is operated in the LOW-SPEED position (fig. 3-14B), the stator leads T1, T2, and T3 are connected to the lines while the stator leads T4, T5, and T6 are connected together. This action connects the pole-phase groups for the consequent-pole, 8-pole, parallel-wye connection. The parallel-wye connection draws more current from the line than the series-delta connection. The constant-horsepower multispeed motor is used to drive certain types of machine tools, such as lathes and milling machines, which require the same horsepower at the high and low speeds.

In the CONSTANT-TORQUE MOTOR the horsepower varies directly as the speed. If the same torque is developed at the high speed as at the low speed, the horsepower and the line current must increase in the same ratio as the motor speed. Therefore, the connections for a constant-torque motor are usually the opposite for those of the constant-horsepower connections.

In all consequent-connected motors producing more than one speed, the standard skip group method of labeling pole phase groups cannot be used. Long jumper connections must be used exactly as specified. A skip of six (6) poles is commonly used as noted in figures 3-14, 3-15, and 3-16. Note the practice of connecting these: pole No. 1 to pole No. 7; 2 to 8; 3 to 9; 4 to 10, and so on.

The connections of the phases in a constant-torque, 2-speed motor are illustrated in figure 3-15. These connections differ from those of the constant-horsepower (fig. 3-14) in that some of the pole-phase groups in each group is reversed. Hence, when the controller is operated to the HIGH-SPEED position (fig. 3-15A), the stator leads, T4, T5, and T6 (T1, T2, and T3 shorted) are connected to the line wires so that the pole-phase groups are connected for the standard 4-pole, parallel-wye connection. When the controller is operated to the LOW-SPEED position (fig. 3-15B), the stator leads, T1, T2, and T3 (T4, T5, and T6 open) are connected to the line wires so that the pole-phase groups are connected for the consequent-pole, 8 pole, series-delta connection. The constant-torque multispeed motor is used to drive equipment, such as conveyors, stokers, and compressors, that require the same torque at both speeds.



Incoming POWER LINES *are denoted by* L1 L2 L3

MOTOR TERMINALS ARE DENOTED *by* T1 T2 T3 T4 T5 T6

Connect the 3-phase lines to the following MOTOR TERMINALS:

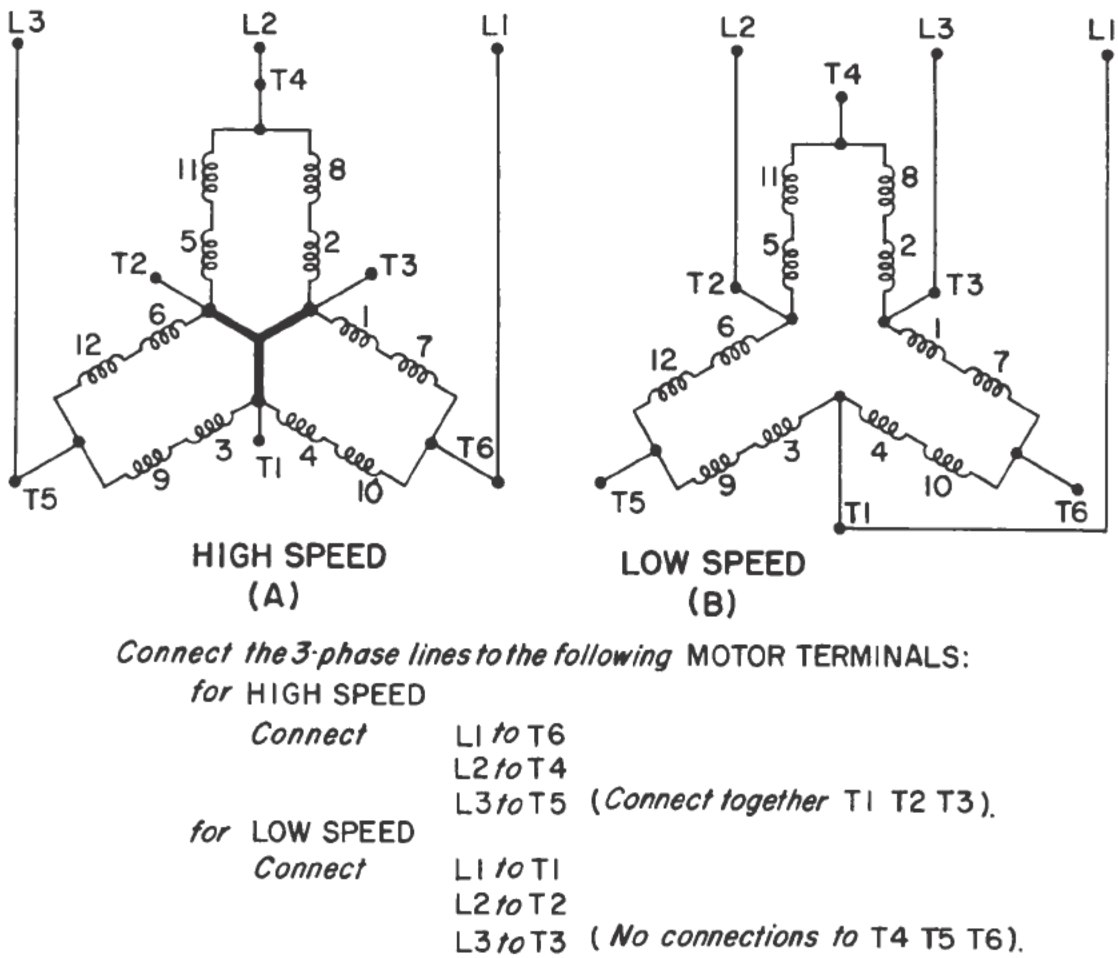
for HIGH SPEED
Connect L1 *to* T6
L2 *to* T4
L3 *to* T5 (*No connections to* T1 T2 T3).

for LOW SPEED
Connect L1 *to* T1
L2 *to* T2
L3 *to* T3 (*Connect together* T4 T5 T6).

111.73

Figure 3-14.—Constant-horsepower winding.

In the VARIABLE-TORQUE, VARIABLE-HORSEPOWER MOTOR the torque and horsepower increase at the high-speed connection. Therefore, the current in a variable-torque, variable-horsepower motor must increase by a greater ratio than is necessary in the constant-torque motor. This increase in current with an increase in speed is accomplished by changing the connections of the pole-phase groups from series-wye at the low speed to parallel-wye at the high speed, as illustrated in figure 3-16.



111.74

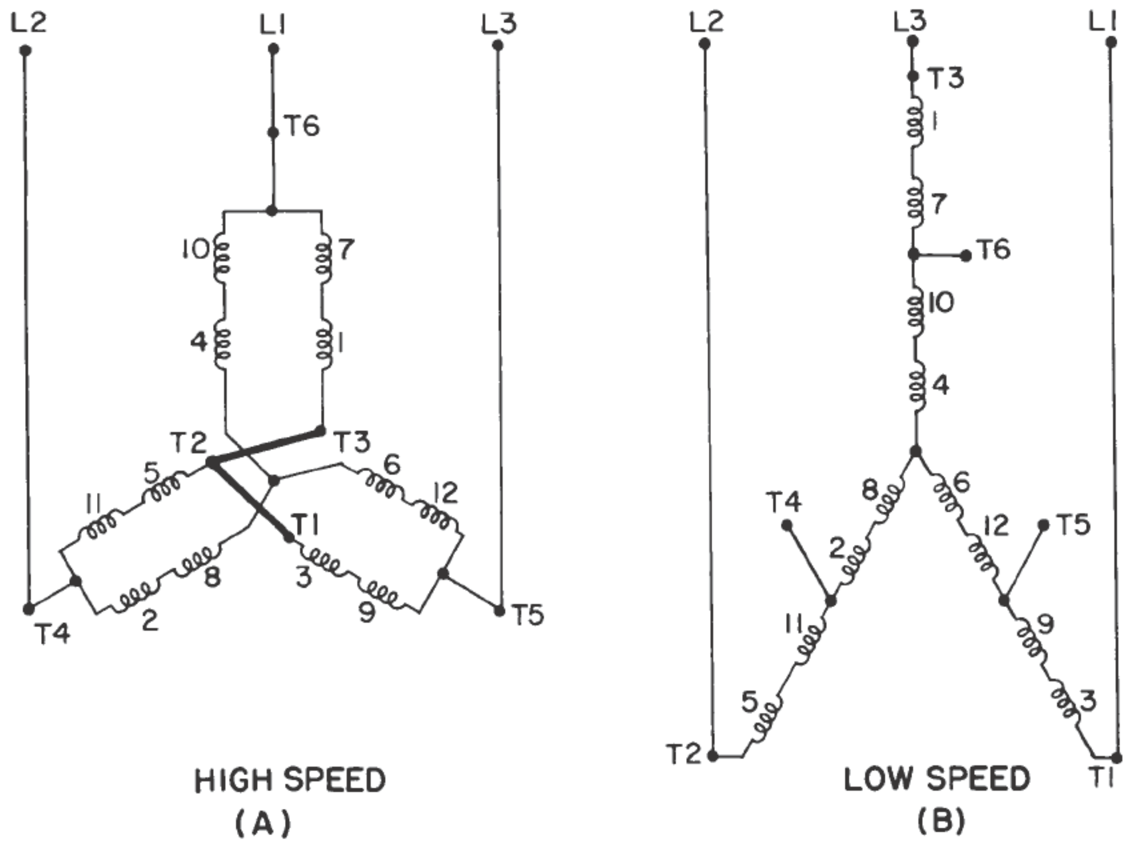
Figure 3-15.—Constant-torque winding.

When the controller is operated to the HIGH SPEED position (fig. 3-16A), the stator leads, T4, T5, and T6 (T1, T2, and T3 shorted) are connected to the line wires so that the pole-phase groups are connected for the standard 4-pole, parallel-wye connection. When the controller is operated to the LOW-SPEED position (fig. 3-16B), the stator leads, T1, T2, and T3 (T4, T5, and T6 open) are connected to the line wires so that the pole-phase groups are connected for the consequent-pole, 8-pole, series-wye connection. The variable-torque, variable-horsepower multispeed motor is used to drive centrifugal pumps and fans that require greater torque at high speeds than at low speeds.

The completed stator winding is checked electrically for continuity and for shorted turns. These tests are described under polyphase stator troubles later in this chapter.

Varnishing

The complete stator is now prebaked and varnish treated in accordance with the procedures listed for class A and class B insulation in table 2-3 of chapter 2. If facilities are not available for baking large and heavy generators and motors used in some propulsion installations, revarnishing can be accomplished by spraying with an air-drying varnish. Air-drying varnish films are less resistant to moisture and are of lower dielectric strength than those films obtainable with the better



Connect the 3-phase lines to the following MOTOR TERMINALS:

for HIGH SPEED

Connect L1 *to* T6
L2 *to* T4
L3 *to* T5 (*Connect together* T1 T2 T3).

for LOW SPEED

Connect L1 *to* T1
L2 *to* T2
L3 *to* T3 (*No connections to* T4 T5 T6).

111.75

Figure 3-16.—Variable-torque winding.

grades of baking varnish. Hence, a baking varnish should be applied whenever feasible.

The Bureau of Ships Technical Manual, chapter 60 contains detailed information concerning the application of varnish.

High Potential Tests

The same general conditions concerning high-potential tests of d-c armatures apply to a-c stators. A high-potential test should not be

made on an a-c generator or motor until after the reconditioning or rewinding is completed, including the application of varnish except in cases of reconditioning when the application of varnish is not necessary, and the insulation resistance is higher than the value given in the "after reconditioning in shop" column of table 3-1. This is because insulation, which is free from defective material and workmanship, and which would prove to be satisfactory if tested when clean and dry, may break down if given a high-potential test at a time when the insulation resistance is low because of dirt or moisture.

To make a high-potential test on all a-c stator windings, except propulsion generators and motors that have been rewound (not merely reconditioned), the test voltage should be applied to the interconnected phase windings by connecting the external leads of all three phases to one terminal of the source of test potential and the other test lead to ground. All other windings and metal parts not to be tested must be grounded.

As in d-c high-potential tests, the test voltage is obtained from a 60-cycle, a-c source having a capacity of 1 kilowatt. When conducting a test, increase the voltage as rapidly as possible without exceeding the correct value indicated on the voltmeter. The full voltage should be maintained for 1 minute and then reduced to one-quarter of the correct value or less in not more than 15 seconds.

The effective (rms) voltage for a high-potential test on a-c generators and motors (that have been restored to a condition which should be as good as new) with a rated voltage below 600 volts should be as follows, except for propulsion generators and motors on electric-drive battleships, and equipment that has been temporarily reconditioned after submergence: armature circuits for a-c machines, 2 x E + 1000 volts and field circuits for a-c machines, 10 x V (in no case less than 1500 volts or more than 3500 volts), where E is the rated stator voltage (line-to-line) and V is the rated excitation voltage.

POLYPHASE STATOR TROUBLES

The methods of locating and correcting the common troubles encountered in rewound and reconnected polyphase stator windings are included for the convenience of Electrician's Mates engaged in this work.

SHORTED POLE-PHASE GROUP

An entire pole-phase group may be shorted in a polyphase stator. Such a defect is usually indicated by excessive heat in the defective part. The trouble can be readily located by a compass test. To conduct a compass test, excite the stator windings with a low-voltage, direct current that will set up the poles in the stator (fig. 3-17). When the windings are excited, a compass is moved around the inside circumference of the stator core. As each pole group is approached, the polarity is indicated by the compass. There should be the same number of alternate north and south poles in a 3-phase winding.

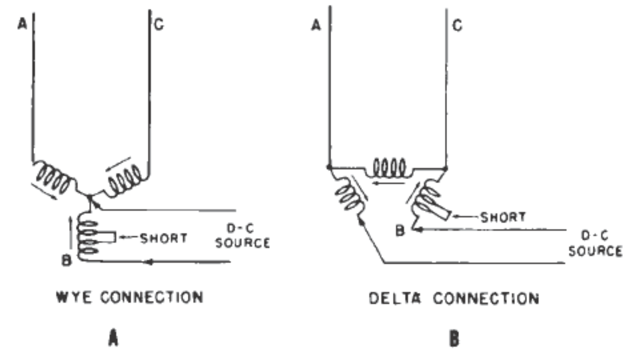
Table 3-1.—Alternating-current Generators and Motors Other Than Propulsion Generators and Motors.

Circuit	Insulation Resistance in Megohms at 25° C*		
	Before cleaning	After Cleaning in Vessel	After Reconditioning in Shop
Stator circuit of generators and motors	0.2	1	2
Rotor circuit of wound rotor induction motors	0.1	0.5	1
Field circuit of generators or of synchronous motors	0.4	2	4

*The figures given are for machines rated 500 volts or less. For machines having a rated voltage, E, greater than 500 volts, multiply all figures given in the table by E/500.

In testing a 3-phase, wye-connected winding (fig. 3-17A), test each phase separately by impressing the d-c voltage successively on each of the phase leads and the midpoint of the wye connection. If there is no trouble in the winding, the compass will indicate alternately north and south for each pole-phase group around the stator. If a complete pole-phase group is shorted, the compass needle will not be deflected at this point.

In testing a 3-phase delta-connected winding (fig. 3-17B), open one of the delta connections and apply the direct current to the winding. The current will flow through the three phases



111.76
Figure 3-17.—Compass test for shorted pole-phase groups.

in series. If the pole-phase groups are connected properly, the compass will indicate alternate north and south poles around the stator frame. As in the wye-connected winding a shorted pole-phase group is indicated by no deflection of the compass needle.

SHORTED PHASE

When an entire phase of a 3-phase winding is shorted, the defect is most readily located by a balanced-current test made with a TYPE TA industrial analyzer.

This test can also be made with an ammeter and low-voltage a-c source (fig. 3-18).

In testing a 3-phase wye-connected winding (fig. 3-18A), test each phase separately by impressing the a-c voltage successively on each of the phase leads and the midpoint of the wye connection. If there is no trouble in the windings, and if the impedance of the windings of each phase is the same, the ammeter will indicate approximately the same value of current for each of the three phases. If one phase is shorted, the ammeter will indicate a higher current reading for this phase than those of the other two phases because the impedance is less.

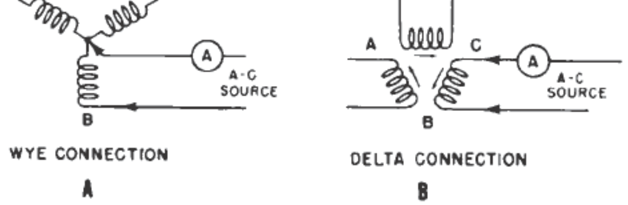
In testing a 3-phase delta-connected winding (fig. 3-18B) open each delta connection and test each phase separately. As in the wye-connected winding, the shorted phase will be indicated by a much higher current reading on the ammeter.

OPEN CIRCUITS

An open circuit in a 3-phase winding can be readily located by means of an ohmmeter (fig. 3-19).

In testing a 3-phase wye-connected winding (fig. 3-19A), connect the ohmmeter leads across each of the phases to locate the defective phase. When the ohmmeter leads are placed on terminals A and C, no open circuit (a low reading) is indicated. However, when the leads are placed on terminals C and B, and then on terminals B and A, an open circuit (a high reading) is indicated in both positions, thus denoting an open in phase B. After the defective phase has been located, test each stub connection of the pole-phase groups with the ohmmeter until the open coil is located.

In testing a 3-phase, delta-connected winding (fig. 3-19B), it is necessary to open one delta connection to avoid shunting the phase being tested. Test each phase separately until the open is located. After the faulty phase is located, test each stub connection of the pole-phase groups, as in the wye-connection, until the open coil is located.



111.77
Figure 3-18.—Balanced current test for shorted phase.

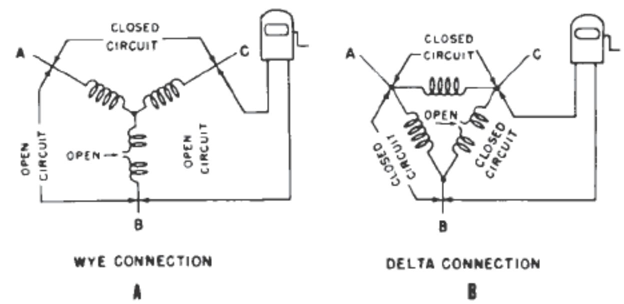


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Figure 3-19.—Ohmmeter test for open circuits.

If the windings are parallel, it is necessary to open each parallel group and test each group separately.

REVERSED COIL

If the leads of a coil that are adjacent to those of another coil are accidentally reversed when connecting the coils together, the polarity of this coil will be reversed with respect to the remainder of the coils and groups of this phase. Thus, the reversed coil bucks all the other coils in the same pole-phase group and the associated portions heat up to a greater extent than the other portions that are connected properly.

Reversed coils in a pole-phase group are readily located by the compass test. The test is conducted in the same manner described for locating a shorted coil. However, instead of no deflection being indicated in the case of a shorted coil, the compass needle will indicate a reversed polarity when placed over the reversed coil. When the reversed coil is located, the fault is corrected by interchanging the connections.

REVERSED POLE-PHASE GROUP

An entire pole-phase group is sometimes accidentally reversed when adjacent pole-phase groups are connected together, which results in two groups having the same polarity. This reversal in polarity of that portion of the winding will result in a distortion of the magnetic field, causing an increase in the magnetic noise of the machine.

The compass test is used to locate a reversed pole-phase group. The test is conducted in the same manner described for locating a shorted coil. However, in this test the compass will indicate three north-pole groups or three south-pole groups adjacent to each other in a 3-phase motor. The middle group of the three is the group that is connected improperly. As described in the test for a reversed coil, check each group separately.

REVERSED PHASE

Three-phase voltage vector diagrams are illustrated in figure 3-20. When a 3-phase winding is connected properly, each of the three phases is spaced 120 electrical degrees apart for a wye-connected winding (fig. 3-20A) and for a delta connected winding (fig. 3-20B). If any one of the three phases of the wye or delta

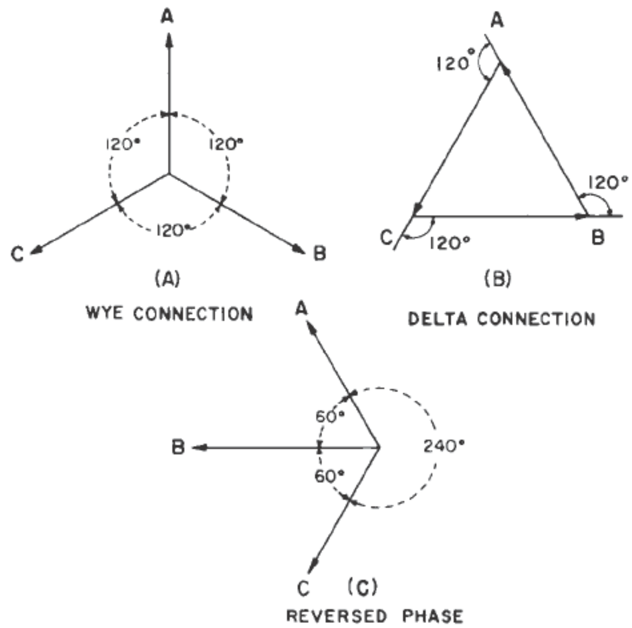

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Figure 3-20.—Three-phase voltage vector diagrams.

connected winding is connected in a reverse direction, the angular relation between the phases is changed (fig. 3-20C). The reversed phase bucks the other two phases so that there is no longer a regular succession of alternate north and south poles around the stator.

The motor will not run except possibly at no load; it emits a loud growling sound, and the temperature of the winding increases rapidly. On the other hand, if one phase of a 2-phase motor is reversed, the motor will run normally without overheating or undue noise, but in the reverse direction.

The compass test can be used to locate a reversed phase. If the winding is wye connected, open the reversed phase at the wye connection and correct the fault. If the winding is delta connected, interchange the leads of the reversed phase to correct the fault.

INCORRECT GROUPING

When a winding is connected, the number of slots per pole-phase group is determined by dividing the total number of slots by the product of the number of poles and the number of phases. If an error is made in counting the groups and

more coils are connected in one phase than in another phase, the currents are unbalanced in all three phases. In other words, the current in the phase having fewer number of coils is higher than normal, whereas the current in the phase having greater number of coils is less than normal. The faulty phase carries the heaviest current when taking current readings of the three phases.

INCORRECT VOLTAGE CONNECTIONS

If the voltage applied to a motor is too high, the windings will become hot and hum excessively at no load. If the motor formerly operated satisfactorily on this voltage, it indicates a wrong connection. If the winding was originally connected in series-wye or series-delta and the winding is now connected in parallel-wye or parallel-delta, then the voltage is twice the value it should be for this connection.

If the winding was originally connected in series-wye and the present connection is in series-delta, the voltage is 73 percent too high for the windings. On the other hand, if the motor apparently operates satisfactorily at no load but loses power and speed at full load, it indicates that the voltage is too low. Also, if a motor was formerly connected in series-delta and is reconnected in series-wye, the voltage is reduced to 57 percent of the original value required.

CHAPTER 4

VOLTAGE AND FREQUENCY REGULATION

Sophisticated electronics and weapons systems aboard modern Navy ships require closely regulated electrical power for proper operation. To meet the increased demand for this closely regulated power, new standards for a-c shipboard power systems have been established, and new voltage and frequency regulating equipments have been developed. Following a brief discussion of these new standards and equipments, this chapter will discuss the various types of voltage regulators for a-c generators in use aboard Navy ships.

TYPES I, II, AND III POWER

Mil-Std-761A (Ships) of 11 Oct. 1963 establishes standard electrical characteristics for a-c power systems. The three basic power supplies (types I, II, and III) are described in table 4-1. The power system characteristics shown in this table are those existing at the load and do not represent generator output characteristics.

The terms used in this table are defined below:

STEADY STATE VOLTAGE LIMITS—Steady state voltage limits are the maximum average voltage variations expressed in percent of nominal utilization equipment voltage rating under steady state load conditions. This includes variations caused by load changes, environment (such as temperature, inclination, meter error, and so forth) as well as drift, but does not include transient load changes.

MAXIMUM VOLTAGE UNBALANCE BETWEEN PHASES (THREE PHASE LOADS)—The maximum voltage unbalance between phases is the difference between the highest and lowest phase voltage expressed in percent of the nominal utilization equipment voltage rating.

MODULATION AMPLITUDE—Modulation amplitude is a periodic voltage variation (peak to valley) about the nominal equipment voltage rating in percent of the nominal utilization equipment voltage rating. This is a cyclic or random disturbance such as may be caused by regulators, reciprocating, or intermittent loads.

$$\text{Modulation } \% = \frac{\text{E max. - E min.}}{\text{E nominal}} \ (100)$$

$$= (\text{Peak or r.m.s.})$$

Note: This is approximately twice the value obtained from generally accepted definitions used by electronics handbooks.

TRANSIENT VOLTAGE LIMITS—A transient is the changing conditions of the voltage which goes beyond the steady state limits and returns to the steady state voltage limits within a specified time period (recovery time). Maximum permissible transient voltage variation is expressed in percent of nominal utilization equipment voltage rating.

VOLTAGE RECOVERY TIME—Voltage recovery time is the time elapsed from initiation of the disturbance until the voltage recovers and remains within the steady state voltage limits.

STEADY STATE FREQUENCY LIMITS—Steady state frequency limits are the maximum frequency variations expressed in percent of nominal system frequency under steady load conditions. This includes variations caused by load changes, environment (such as temperature, inclination, meter error, or other factors) as well as drift, but does not include transient changes.

TRANSIENT FREQUENCY LIMITS—A transient is the changing condition of the frequency which goes beyond the steady state limits and returns to the steady state frequency limits within a specified time period (recovery time). Maximum permissible transient frequency variation is expressed in percent of nominal system frequency rating.

Table 4-1. —Standard Electrical Characteristics for Shipboard A-C Power Systems

	Type I	Type II	Type III
A. Nominal utilization voltage	440 or 115	440 or 115	440, 115 or 115/200
B. Nominal frequency	60 or 400	60 or 400	400
C. Steady state voltage			
1. Steady state tolerance band			
a. Average line to line voltage for 3 phase	±5%	±1%	±1/2%
b. Line to line voltage for single phase of 3 phase system	±8%	±3%	±1/2%
2. Unbalance between phases	3%	2%	1%
3. Modulation amplitude (Note 1)	2%	2%	1%
D. Transient voltage			
1. Transient voltage limits	±18%	±18%	±5%
2. Recovery time	2 sec.	0.25 sec. at 400 cycles 0.75 sec. at 60 cycles	0.25 sec.
E. Steady state frequency band	±5%	±5%	±1/2%
F. Transient frequency			
1. Transient frequency limits (Note 2)	±3%	±3%	±1%
2. Recovery time	2 sec.	2 sec.	0.25 sec.
G. Waveform			
1. Total harmonic content	5%	6%	3%
2. Maximum single harmonic	3%	4%	2%
3. Deviation factor	-	-	5%

Note 1: Not included in steady state limits.
Note 2: With frequency transients of 3%, only 1% shall be outside the steady state frequency tolerance band for Types I and II power.

FREQUENCY RECOVERY TIME—Frequency recovery time is the time elapsed from initiation of disturbance until frequency recovers and remains within the steady state frequency limits.

HARMONIC CONTENT—The harmonic content of a voltage wave is the ratio expressed as a percent of the effective value of the residue after the elimination of the fundamental to the nominal utilization equipment voltage rating.

SINGLE HARMONIC—The maximum single harmonic expressed in percent of the effective value of the single harmonic to the nominal utilization equipment voltage rating.

DEVIATION FACTOR—The deviation factor of the voltage wave is the ratio of the maximum difference between corresponding ordinates of the voltage wave and of the equivalent sine wave to 1.414 times the nominal voltage when the waves are superimposed to make the maximum difference as small as possible. This does not apply to ordinates within 10 electrical degrees on either side of zero voltage.

$$\text{Deviation factor } \% = \frac{\text{Max. deviation}}{\sqrt{2}\text{ nominal voltage}} \; (100)$$

Present ship service generators and distribution systems are adequate for 60 and 400 cycle type I power. Type II power differs principally from type I in having more stringent voltage requirements. Better voltage regulation at the ship service generator will not satisfy these voltage requirements as the specified voltage is at the equipment or load and not at the generator output. Static type line voltage regulators which provide type II voltage control at the load are being evaluated by the Bureau of Ships. Figure 4-1A shows a schematic diagram

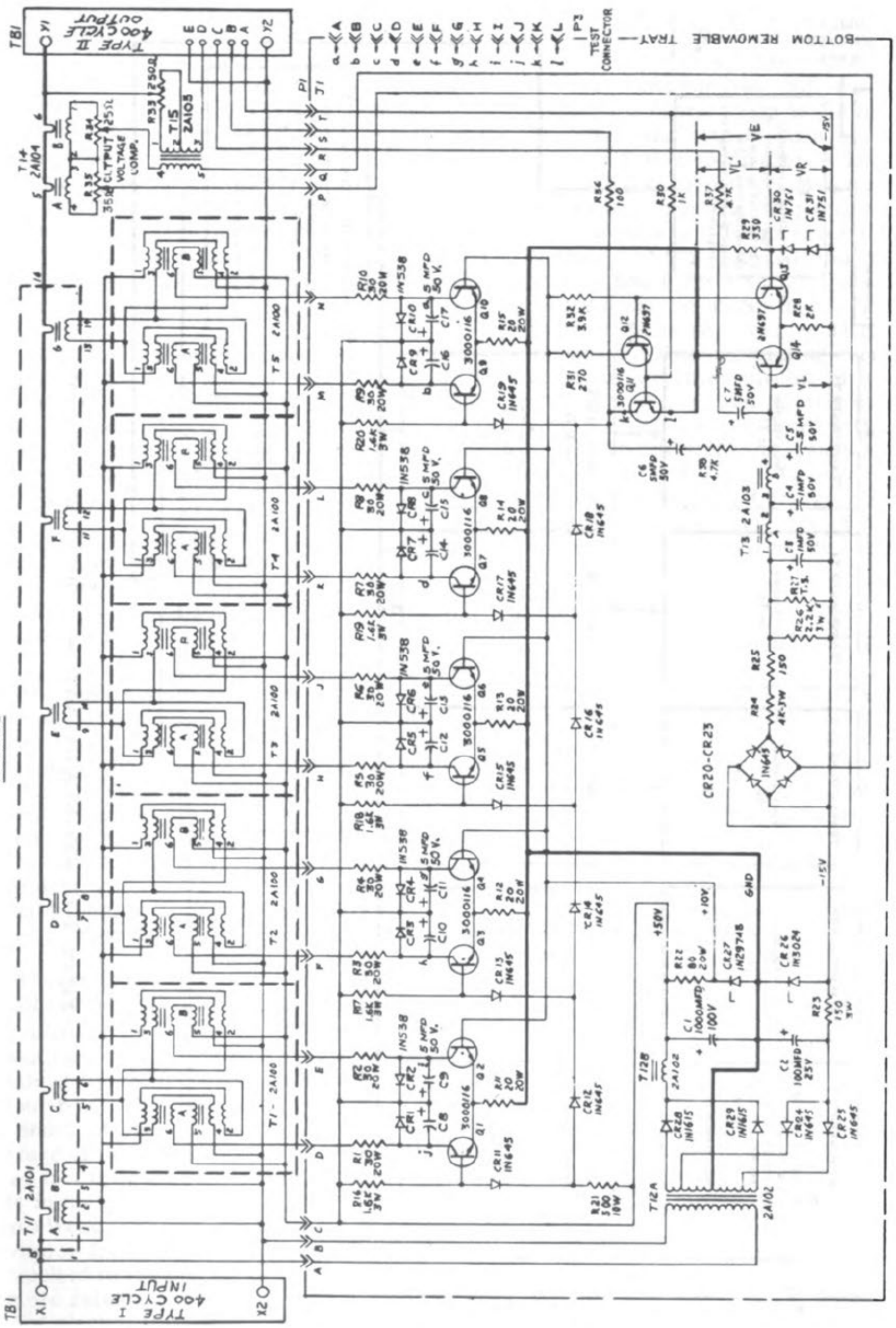

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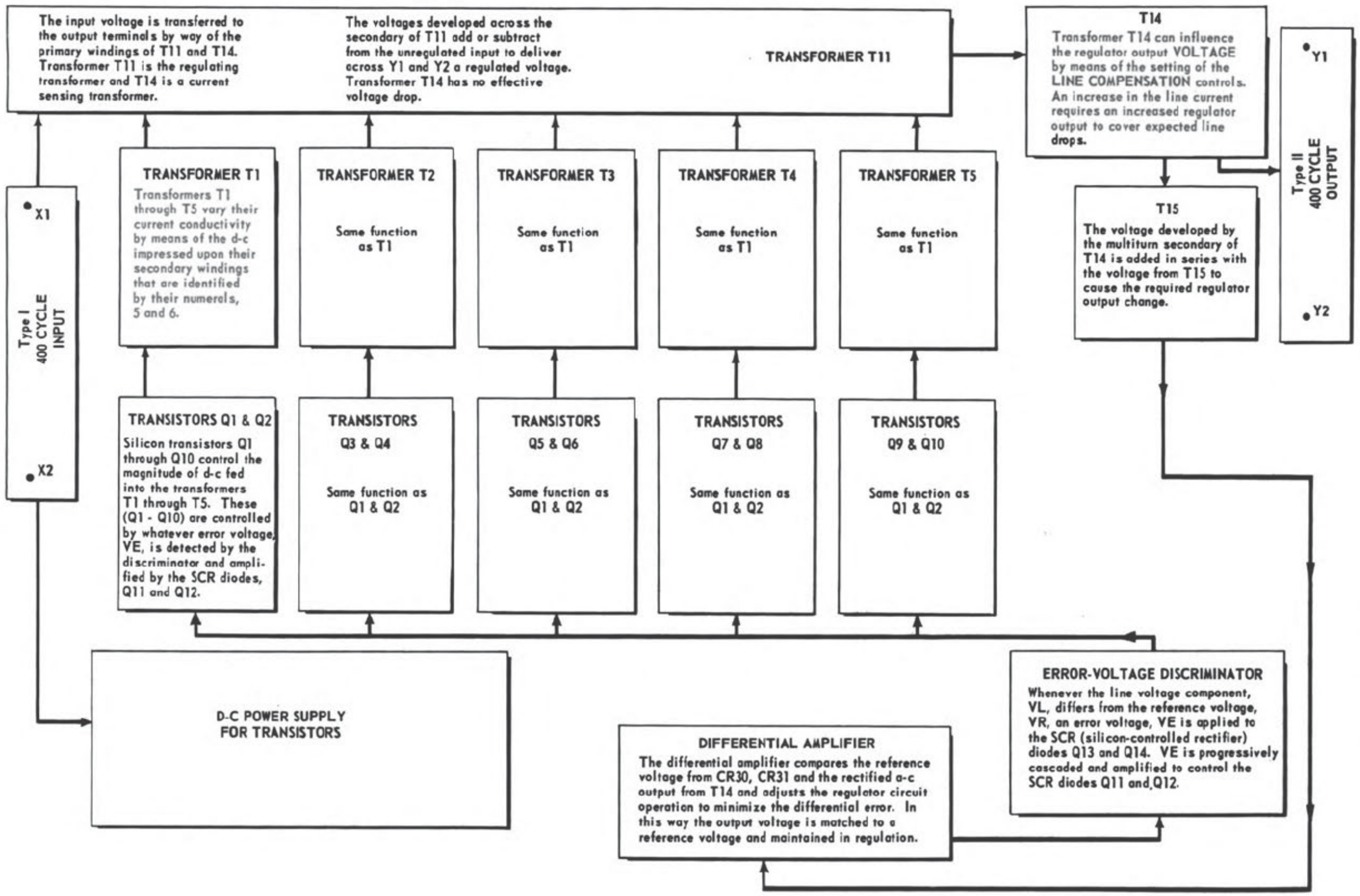
Figure 4-1A.—25-KVA line voltage regulator. Schematic diagram.



111.21

Figure 4-1B.—25-KVA line voltage regulator. Block diagram.

of a 25 kva line voltage regulator. A description of operation appears in figure 4-1B.

The voltage and frequency requirements for type III power cannot be met without isolating the equipment requiring the power from the rest of the power system. Motor generator sets have normally been used for this purpose. Motor generator sets that provide 400 cycle closely regulated power are discussed in the I.C. training courses. Static type inverters and converters are under development and are replacing the motor generator sets.

Electric load-sensing speed governors have been developed for ship service generators in electrical systems requiring better frequency control than possible with mechanical type governors. Electric governors have been successfully used on both steam-turbine and diesel generators.

An electric governor may be operated as an isochronous governor (constant speed at all loads) or with speed droop which permits paralleling with other generators having conventional fly-weight governors.

The operation of a typical electrical load-sensing governing system may be generally described as follows. The steam valve or throttle controlling the prime mover fuel supply is operated by an electro-hydraulic actuator which responds to the output of a magnetic amplifier. Generator speed and load signals are fed into the magnetic amplifier to produce an output of sufficient power to operate the electro-hydraulic actuator which correctly positions the steam valve or throttle.

The speed signal is usually provided by a small permanent magnet generator driven from the shaft of the prime mover or ship service generator. The speed signal is sometimes obtained by sensing the ship service generator output frequency but the loss of signal in case of short circuit on the generator is a disadvantage of this method. The speed signal is applied to a frequency sensitive and reference circuit in the governor control unit. The output of this circuit is an error signal if there is any deviation from rated speed. This error signal is applied to the magnetic amplifier and acts to restore rated speed. Stability is obtained by the use of electrical feedback circuits.

Load measuring circuits are used in the electric governor to obtain proper load ratio on each paralled generator. Most governing systems are designed so that any change in load produces a signal which is fed into the magnetic amplifier and acts in such a way as to offset any anticipated speed change due to load change. The load measuring circuits on governors of all generators operating in parallel are connected by a tie cable. The governor may be designed or preset so that each paralleled generator will equally share the total load or a load ratio adjustment may be provided. Any deviation in proper load ratio produces a circulating current in the tie cable. This circulating current acts in the magnetic amplifier circuit to increase or decrease fuel supplied to the generator prime movers until proper load ratio is achieved.

The steady state and transient frequency requirements for Type III power can be met with electric governors of the type just described, however, a motor generator or static converter would still be required for Type III voltage control.

TYPES OF VOLTAGE REGULATORS

A voltage regulator consists essentially of a control element and associated mechanical or electrical means to produce the changes in the generator field current that are necessary to maintain a predetermined constant generator terminal voltage. When used on d-c generators, the functions performed by voltage regulators and their auxiliary equipment are to maintain the generator terminal voltage within specified limits and to provide for proper division of the load between generators operating in parallel. When used on a-c generators the functions performed by voltage regulators and their auxiliary equipment are to maintain the generator terminal voltage within specified limits, and to provide for proper division of the reactive current between generators operating in parallel.

The types of voltage regulators used in naval vessels are (1) the indirect acting rheostatic, (2) the direct acting rheostatic, (3) the rotary amplifier, and (4) the combined static excitation and voltage regulation system.

The indirect acting rheostatic type voltage regulators were used on all a-c ship's service generators and many emergency generators until 1943. Many of these voltage regulators are still

in service, but the indirect acting rheostatic type is no longer used for new installations. The present practice for a-c generators is to use the direct acting rheostatic type, the rotary amplifier type, or the combined excitation and voltage regulation system. The type used depends on which is considered most suitable for a particular application. Voltage regulators for d-c generators are usually of the direct acting rheostatic type.

When voltage regulators are used for either a-c or d-c generators, one regulator is provided for each generator that is to be regulated. In some ship's service installations a spare voltage-sensitive (control) element is installed on the switchboard. The switchboard is provided with a transfer switch so that a spare element can be placed in service if either of the other control elements become deranged. Spare control elements are not installed for voltage regulators used on emergency generators.

INDIRECT ACTING TYPE

The indirect acting rheostatic type of voltage regulator consists essentially of a control element and a motor-operated rheostat, which is connected in the field circuit of the a-c generator being regulated. A small motor, which is controlled by the control element, drives a contact arm over the contact segments on the field rheostat and changes the field resistance.

The installation of indirect acting voltage regulators used on a-c ship's service generators is illustrated by the simplified block diagram in figure 4-2A. The installation includes two complete voltage regulator equipments and one emergency, or spare, control element mounted on each switchboard. A TRANSFER SWITCH is provided to substitute the spare element for either of the other two elements in an emergency.

The complete voltage regulator system for one a-c generator includes a (1) control element, (2) motor-operated rheostat, (3) contactor panel, and (4) compensator.

Control Element

The control element is located on the switchboard and controls the motor-operated rheostat to adjust the generator voltage automatically when necessary to compensate for changes in load on the a-c generator.

This control element (fig. 4-2B) consists of a torque motor, which carries a moving arm with two sets of contacts, and two antihunt devices. The torque motor is made up of a stationary coil mounted on a C-shaped iron core or frame. The moving arm, which is nonmagnetic, is pivoted at the top of the magnet frame. A small iron armature, attached to the moving arm on one side of the pivot is located so that the armature can move in the fixed air gap of the magnetic circuit. A coiled spring, attached to the armature on the other side of the pivot, is located so that the magnetic pull of the iron armature is balanced by the tension of the coiled spring.

The normal-response contacts, R and L, and the quick-response contacts, AR and AL, are located on opposite ends of the moving arm. Each of the normal response contacts, R and L, consists of a spring contact mounted on one end of the moving arm, and a stud contact mounted on the armature of the normal antihunt device, NH. Similarly, each of the quick-response contacts, AR and AL, consists of a spring contact, mounted on the opposite end of the moving arm, and a stud contact mounted on the armature of the quick antihunt device, QH.

The normal-response contacts control the motor-operated rheostat and adjust the generator voltage automatically to compensate for small changes in load on the a-c generator. The quick-response contacts control the field-forcing contactors, QR and QL, to compensate for relatively large changes in load. This action restores the generator voltage to the range for which the normal response contacts will take over control.

The normal antihunt device, NH, and the quick-antihunt device, QH, are located on each side of the regulator element below the associated normal-response contacts and quick-response contacts. The antihunt devices function to separate the regulator contacts shortly after they have closed due to a small deviation from normal regulated voltage and to provide a predetermined interval for the motor-operated rheostat to make a correction in the excitation prior to the contacts of the antihunt device returning to their normal position.

The schematic diagram of an indirect acting voltage regulator for a single generator with a compensator for paralled operation is illustrated in figure 4-3. The regulator coil is energized

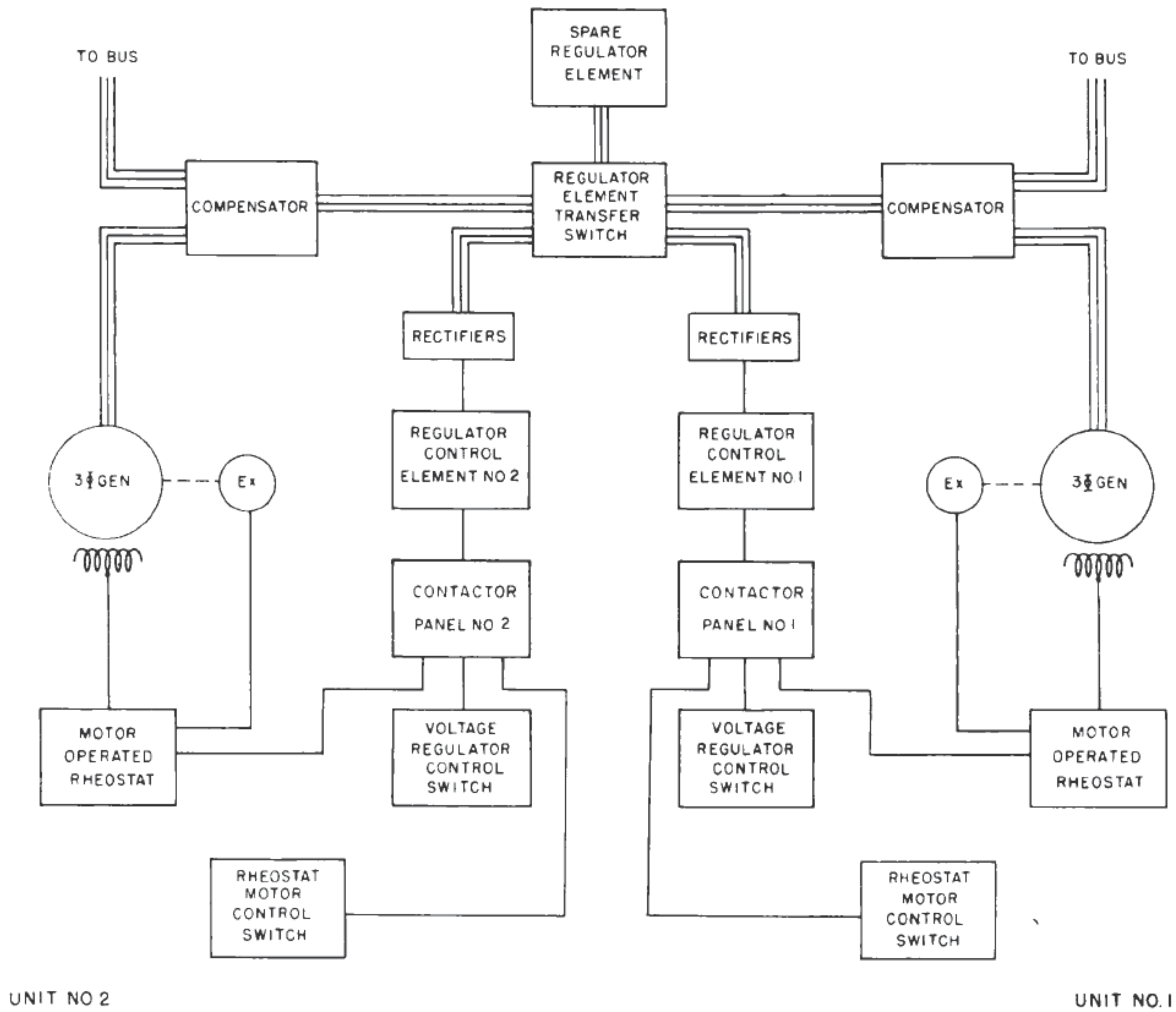


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Figure 4-2A.—Block diagram of indirect acting voltage regulator installation.

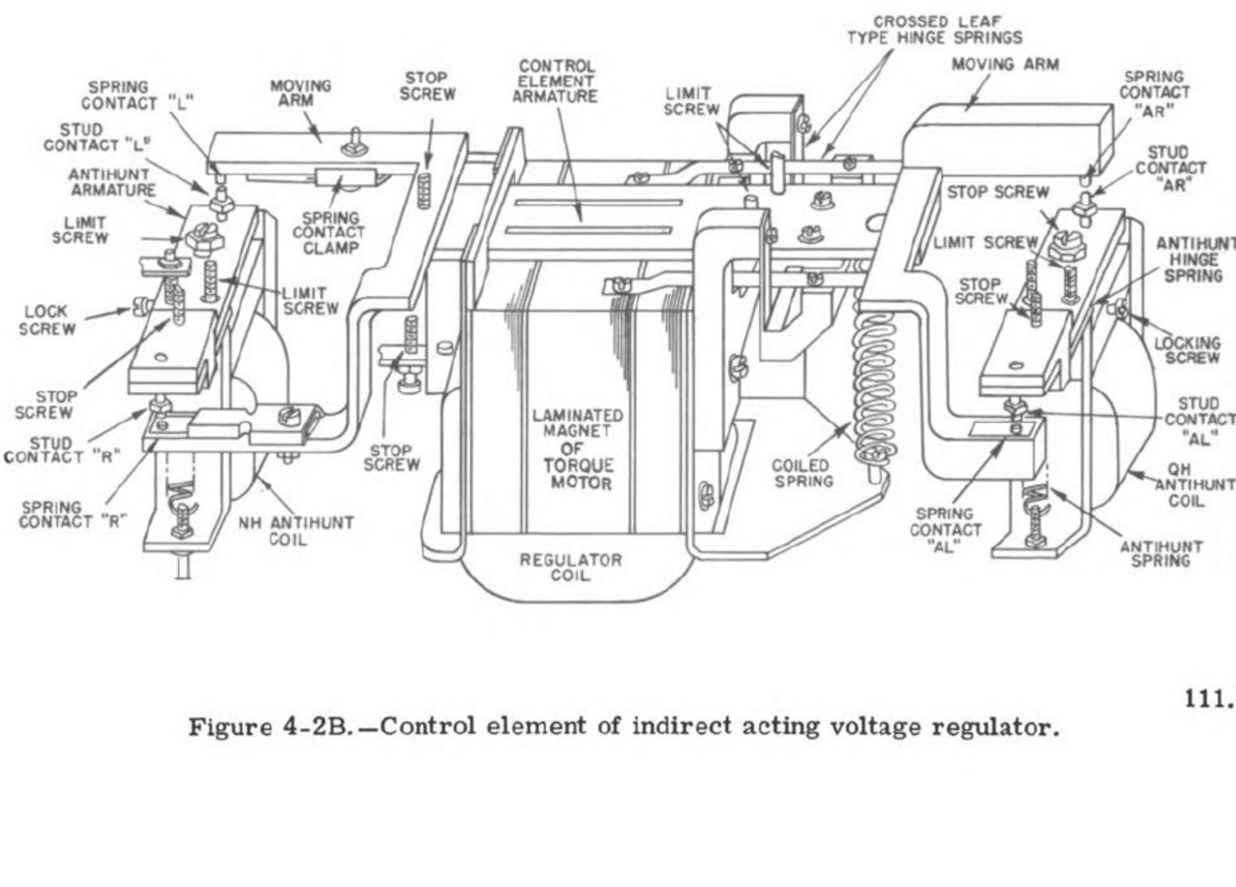

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Figure 4-2B.—Control element of indirect acting voltage regulator.

from the d-c side of a 110-volt, 3-phase, full-wave metalic oxide rectifier. The a-c side of the rectifier is supplied through two open-delta potential transformers connected to the 440-volt, 3-phase, a-c generator voltage. Hence the regulator responds to a direct voltage, which is proportional to the average of all three phases of the 3-phase alternating voltage. The regulator adjusts the generator field rheostat to the position required to maintain normal voltage by means of the rheostat motor control relays and the high-speed, field-forcing contactors.

The VOLTAGE ADJUSTING RHEOSTAT, R2, is used to increase or decrease, the value of resistance in the d-c coil circuit of the regulator. Turning the handle of the rheostat either raises or lowers the value of the a-c generator voltage that the regulator maintains. An adjustable resistor, R1, is connected in series with the voltage adjusting rheostat.

The VOLTAGE REGULATOR CONTROL SWITCH has three positions (manual, indicating, and regulating). In the manual and indicating positions, contacts M-I are closed; in the regulating and indicating position, contacts R-I are closed; and in the regulating position, contacts R are closed. When the regulator control switch is in the MANUAL position, the regulator is cut out of the circuit and a circuit is completed to the rheostat motor control switch, which has three positions (raise, off, and lower). The handle of this switch is spring loaded so that it returns to the normally OFF position when released.

When the handle of the rheostat motor control switch is turned the the RAISE position, contacts CSR close to complete a circuit to the S2 coil of the rheostat motor, which turns the rheostat arm in a direction to reduce the resistance in the generator field circuit. When the handle is turned to the LOWER position, contacts CSL close to complete a circuit to the S1 coil of the rheostat motor, which turns the rheostat arm in a direction to increase the resistance in the generator field circuit.

In addition to the manual operation by the voltage regulator control switch and the rheostat motor control switch, the rheostat can be operated by a handwheel located on the front of the switchboard.

When the regulator control switch is in the INDICATING position (contacts M-I closed), the generator voltage is controlled manually by the rheostat motor control switch. However, the regulator element is energized and its operation is indicated by two indicating lamps, RL and LL, which show whether the regulator element is attempting to raise or lower the voltage.

The two INDICATING LAMPS enable the Electrician's Mate to adjust properly the control element when it is transferred IN and OUT of service. When the excitation is correct to make such a transfer (a-c voltage normal), both indicating lamps are lighted. When the excitation is incorrect to make a transfer (a-c voltage above or below normal), either the raise or lower lamp is shunted (light goes out) to indicate that a change in excitation is taking place and also to indicate the direction of the change. The lamp, RL, indicates raise and the lamp, LL, indicates lower. Examples of this action are described in this chapter.

When the regulator control switch is in the REGULATING position (contacts R closed), the generator voltage is under the control of the voltage regulator.

Motor-Operated Rheostat

The motor-operated generator field rheostat, R4, which is mounted separately from the switch (fig. 4-3), provides a means for changing the resistance in the a-c generator field circuit either manually or automatically under control of the voltage regulator element. The motor operated rheostat consists of a heavy-duty faceplate mounted in a steel frame. The faceplate is provided with contact segments (in a circular arrangement), which are connected to a suitable resistance unit located in the upper portion of the rheostat frame.

The rheostat control arm is driven by a d-c split-field, series motor. This type motor is used because it permits readjustment of the speed to meet operating conditions and requires minimum control apparatus. A tapped resistor is connected in series with the armature to provide control of the motor speed. Normally the factory adjustment is sufficient.

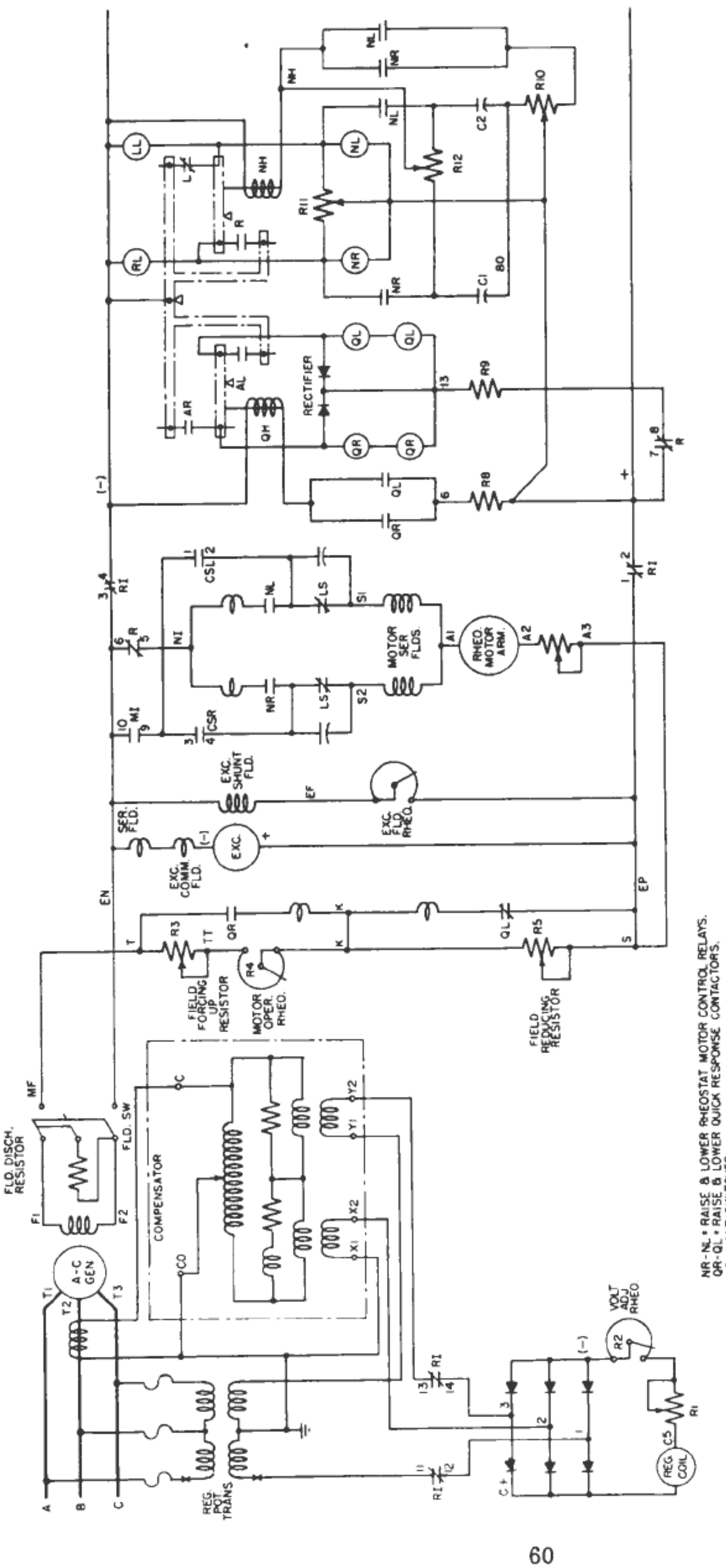

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Figure 4-3.—Indirect acting voltage regulator system.

Contactor Panel

The contactor panel is hinged to the lower portion of the rheostat frame containing the faceplate. The contactor panel contains two small contactors (raise and lower) for energizing the rheostat motor in either the forward or the reverse direction under the control of the voltage regulator and the rheostat motor control switch. The panel also contains two heavy-duty, high-speed contactors field forcing up, QR, and field forcing down, QL, for restoring the voltage more quickly to normal when relatively large changes in load occur.

Compensator

When two or more regulator-controlled a-c generators operate in parallel on the same bus, it is necessary to equalize the amount of reactive current carried by each generator. This equalization of reactive current is accomplished by giving a regulator a drooping characteristic by means of a cross-current compensator provided with each a-c generator and associated regulator.

The compensator (fig. 4-3) consists of a tapped autotransformer connected across a resistor-reactor combination. The autotransformer is energized from a current transformer connected in the B-phase of the a-c generator between the generator terminals and the bus. Two insulating transformers having a 1-to-1 ratio, pick up the voltage drops from the resistor-reactor combination. The output potential terminals of these transformers (X1, X2, Y1, and Y2) are connected in series with the a-c potential leads between the secondaries of the two 440/110-volt open data potential transformers and the 3-phase, full-wave rectifier that supplies direct current for the regulator coil. The compensator is designed to supply compensating voltages in two legs of the 3-phase regulator potential circuit to ensure that a balanced 3-phase voltage is applied to the regulator element.

The taps on the autotransformer are connected to two DIAL SWITCHES (not shown)on the compensator faceplate. One of these switches provides a coarse adjustment and the other a fine adjustment of the compensator. A total of 24 steps is available on the two switches, which, in the case of the standard 12-percent compensation, gives a one-half percent change in compensation per step. The 12-percent compensation is based on 4 amperes supplied from the current transformer. If the current transformer ratio should give some other value of secondary current, the compensation settings will be affected proportionally. The compensating droop introduced by the compensator should be set to approximately 6 percent from no load to full load at 0.8 lagging power factor. However, once the proper connections and settings have been made, no further adjustments should be necessary.

Operation

When the regulator element transfer switch is in the NORMAL position, the regulator control switch in the REGULATING position and the generator circuit breakers closed, the voltage regulator is energized and in control. Note that the generator circuit breakers are not shown in the figure. Assume that the field switch is closed. If the a-c generator voltage is normal, all parts of the regulator are stationary, the control element moving arm is in the midposition, and the two indicating lamps are lighted brightly.

If a small drop in voltage takes place and requires correction, the normal contacts, R (in the control element) close and shunt the indicating lamp, RL, causing it to go out, and also energize the rheostat motor control relay, NR (fig. 4-3).

Relay NR energizes the rheostat motor, which turns the generator field rheostat to cut out resistance and thus to increase the generator field current. At the same time, the operating coil of the normal response antihunt device, NH, is energized, This action moves the antihunt armature to increase the distance between the R contacts and thus to open the circuit at this point. The action of the capacitor, C1 (connected in series with a portion of R10 across the NR coil) maintains the current in the coil for a sufficient time to permit the rheostat motor to move the rheostat arm approximately one step.

The action of the antihunt device, NH, in increasing the distance between the R contacts is only momentary; the contacts return to their

normal position in two or three seconds. If further movement of the generator field rheostat is required, the R contacts will again close and continue the notching action, as required.

If a small increase in voltage takes place and requires correction, the sensitive-element contacts, L, close to lower the voltage. The action is similar to that which occurs to increase the generator voltage.

If a large drop in voltage occurs, the normal-response contacts, R, on the regulator close, followed by the closing of the quick-response contacts, AR. The AR contacts complete the circuit to the quick-response, field-forcing-up contactor, QR. This action short circuits a block of resistance, R3, in the generator field circuit to apply full exciter voltage to the field circuit, thereby rapidly restoring the generator voltage toward normal.

When the field-forcing contactor, QR, closes, it energizes the operating coil of the quick antihunt device, QH, which moves its armature to increase the distance between the quick-response contacts, AR. This action is similar to that described for the normal antihunt device, NH, and the normal-response contacts, R. Hence, if the deviation from normal voltage is within the recalibration of the QH antihunt device, the field-forcing-up contactor, QR, will close and open rapidly while the rheostat arm approaches the required new position.

If the deviation from normal voltage is greater than the recalibrated setting of the QH antihunt device, the field-forcing-up contactor, QR, will close and remain closed until the voltage is brought within the setting of the antihunt device. However, when the alternating voltage is brought within the setting of the quick-response contacts, AR, the normal-response contacts, R, take control and step the rheostat to return the alternating voltage to normal. The rheostat arm turns steadily during the time the quick-response contacts are closed, thus requiring a minimum of additional movement after the normal-response contacts take control to return the voltage to normal.

Similarly, when a large load is removed from the generator (causing a large increase in voltage) the quick-response contacts, AL, close and energize the quick-response, field-reducing contactor, QL, which opens its normally closed contacts. This action inserts a block of resistance, R5, in the generator field circuit, causing the generator voltage to fall rapidly. When the alternating voltage is brought within the setting of the quick-response contacts, AL, the normal-response contacts, L, take control and step the rheostat to return the alternating voltage to normal.

To place the voltage regulator in control for the first time, be certain that the generator line circuit breaker is open and the generator speed and exciter voltage are normal. Place the regulator control switch in the MANUAL position and check the operation of the a-c generator field rheostat. In this position the rheostat is under REMOTE MANUAL CONTROL by means of the rheostat motor control switch. The regulator element and the regulator contact circuits are not energized. With the generator field circuit open, turn the rheostat motor control switch to the LOWER and then to the RAISE position. Observe the operation of the rheostat for proper direction of operation, proper operation of limit switches, and free action of moving parts.

With the regulator control switch still in the MANUAL position, close the generator field switch and observe the effect of the field-forcing-up contactor, QR, by carefully closing it momentarily by hand. Be sure to observe the necessary safety precautions.

The voltage should increase when QR is closed. In a similar manner observe the action of the field-reducing contactor, QL, to determine that the connections have been properly made to these devices. The voltage should decrease when QL is opened.

Next, turn the regulator control switch to the INDICATING position. In this position, the regulator main coil is energized from the potential transformers, and the exciter voltage is applied to the regulator circuit, which includes the normal-response contacts, R and L; the rheostat motor control relays, NR and NL; the antihunt circuits; and the regulator position indicting lamps, RL and LL. If either the R or L contacts close, one or the other of the indicating lamps will go out, and the other will remain lighted. The regulator contacts that are closed can also be determined by inspection, and the voltage adjusting rheostat turned to the

position where the lever arm is balanced between the contacts so that both indicating lamps are lighted brightly.

With the regulator control switch still in the INDICATING position, turn the voltage adjusting rheostat manually in either direction through a small angle to observe the proper operation of the NR and NL relays. At the same time, observe the contact-spreading action of the antihunt device and the proper closing of the NR and NL auxiliary contacts.

Normal alternating voltage can now be obtained by using the rheostat motor control switch to turn the a-c generator field rheostat to the proper position. Then by means of the voltage adjusting rheostat determine the position where both indicating lamps are lighted, thus indicating that the regulator lever arm is floating between the contacts. The regulator control switch can now be turned to the REGULATING position, thus placing the regulator in control of the alternating voltage.

If the voltage adjusting rheostat is turned through a small angle, the regulator will operate to either raise or lower the voltage by means of the R or L contacts and the NR or NL rheostat motor control relays. If the voltage adjusting rheostat is turned quickly through a larger angle, the AR or AL contacts will operate the field-forcing-up or the field-reducing contactors, QR or QL, to bring the voltage to the new setting.

When the normally open field-forcing-up contactor, QR, closes, the voltage will rise rapidly, and, at the same time, the motor-operated field rheostat will move in a direction to reduce the resistance in the field circuit. (As mentioned previously, the R contacts of the control elements must close before the quick response contacts, AR close.) Similarly, when the normally closed field-reducing contactor, QL, opens, the voltage will decrease rapidly and the motor-operated rheostat will move to increase the resistance in the generator field circuit. These conditions must be obtained for satisfactory operation of the voltage regulator. After proper operation of the regulator has been determined, the generator can be connected to the load by closing the generator line circuit breakers. Be sure to follow the standard procedure for paralleling generators if another generator is involved.

To remove the voltage regulator from service, turn the regulator control switch to the INDICATING position at a time when the regulator is at rest, as indicated when both indicating lamps are lighted brightly.

Maintenance

Maintenance of a voltage regulator shall follow the specific instructions given in the manufacturer's manual. Such instructions are summarized by these fundamental procedures: (1) Keep equipment clean and dry. (2) Keep electical connections and mechanical fastenings tight. (3) Inspect and test at the recommended intervals to make sure that the equipment is in operating condition.

For indirect acting, rheostatic type voltage regulators, see that the connections to the contacts of the voltage-sensitive element and relays are given the correct direction of rotation to the pilot motor of the field rheostat.

See that the resistance buttons of the rheostat are tight, with no tendency toward tilting or movement from side to side as the brushes of the contact arm pass over them.

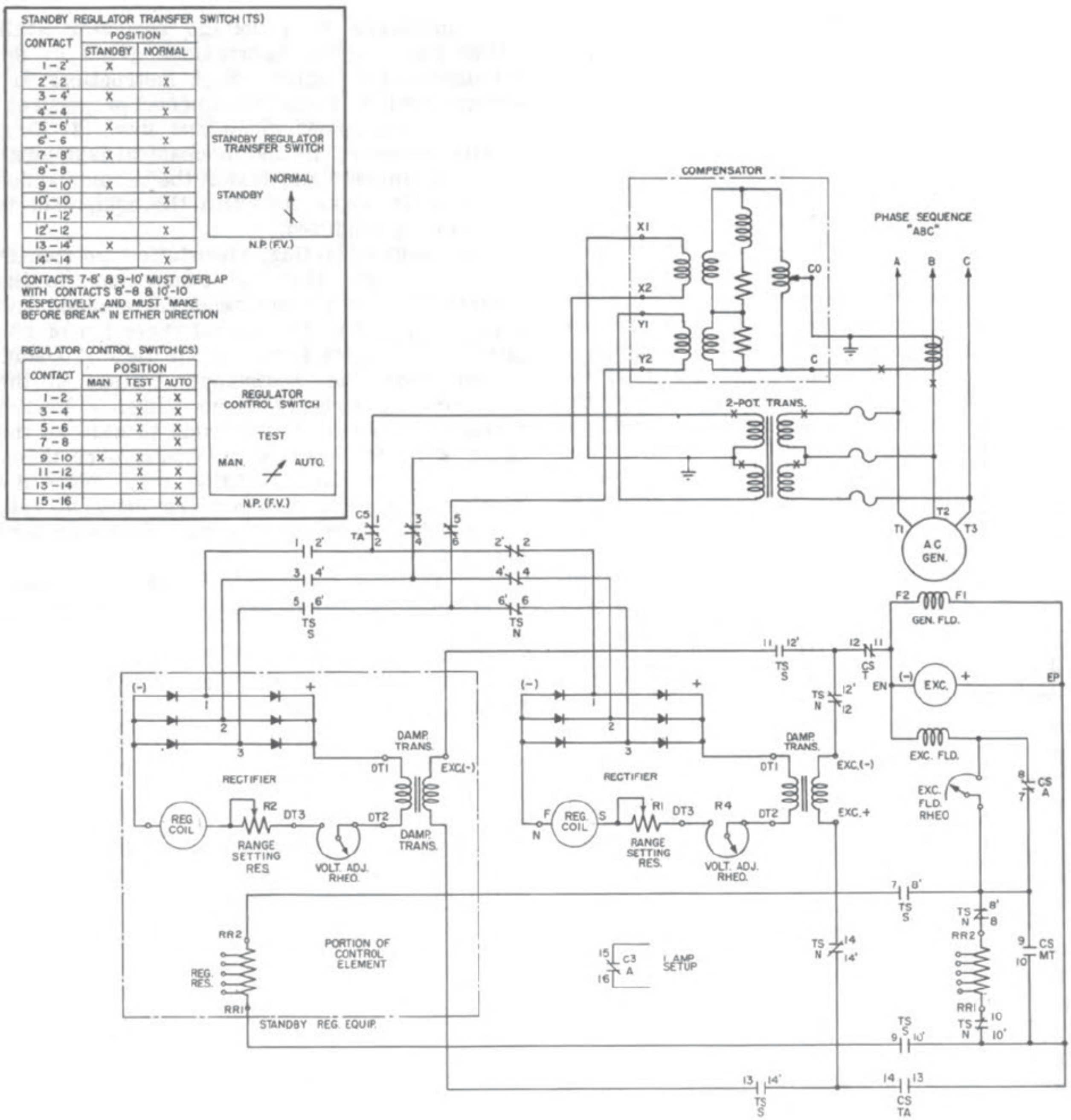
Any movement or tilting may cause the brushes to stick in their holders, cause an arc, and result in a burnout or fusion between buttons.

See that the commutator of the pilot motor is clean and smooth, and is not excessively worn.

DIRECT ACTING RHEOSTATIC VOLTAGE REGULATOR

The direct acting rheostatic type of voltage regulator consists of a control element in the form of a torque motor (regulator coil) which exerts a mechanical force directly on a special type of regulating resistance. When the direct acting regulator is used on d-c generators or small a-c generators, the regulating resistance is usually connected in the field circuit of the generator being controlled. When used on large a-c generators, the regulating resistance is usually connected in the field circuit of the exciter. This arrangement eliminates the need for a rheostat in the a-c generator field circuit and permits the use of much smaller voltage regulator equipment because the exciter field power is much less than the a-c generator field power.

The installation of direct acting (silverstat type) voltage regulators used on ship's service a-c generators is illustrated by the schematic diagram in figure 4-4. The installation includes two complete voltage regulators and one spare or



CONTACT	POSITION	
	STANDBY	NORMAL
1 – 2'	X	
2' – 2		X
3 – 4'	X	
4' – 4		X
5 – 6'	X	
6' – 6		X
7 – 8'	X	
8' – 8		X
9 – 10'	X	
10' – 10		X
11 – 12'	X	
12' – 12		X
13 – 14'	X	
14' – 14		X

CONTACT	POSITION		
	MAN	TEST	AUTO
1 – 2		X	X
3 – 4		X	X
5 – 6		X	X
7 – 8			X
9 – 10	X	X	
11 – 12		X	X
13 – 14		X	X
15 – 16			X

27.20

Figure 4-4.—Schematic diagram of direct acting voltage regulator installation.

standby regulator. A transfer switch is provided for replacing the normal regulator(s) with the standby regulator.

The voltage regulator controls the voltage of the a-c generator by the variable regulating resistance, which is built into the regulator, and is connected in series with the shunt field of the exciter. The complete regulator includes (1) a control element, (2) a damping transformer, and (3) a cross-current compensator.

Control Element

The control element (fig. 4-5) consists of a torque motor, which carries a spring-mounted moving arm and a regulating resistance. The torque motor, similar to that used in the indirect acting control element, comprises a stationary coil wound on a C-shaped iron core and a spring-mounted moving arm. The non-magnetic spring-mounted moving arm is pivoted so that an iron armature attached to one end is centrally located in the fixed air gap of the magnetic circuit. A pusher arm and a coiled spring are attached to the other end of the moving arm. The pusher arm carries two insulated pusher pins arranged to bear against silver buttons, which are spring mounted and connected to the regulating resistance.

The silver buttons are individually mounted on leaf springs insulated from each other and connected to consecutive taps on the stationary regulating resistance plates (fig. 4-6). The resistance plates consists of tapped resistance wire embedded in vitreous enamel. The control element includes two resistance plates, one for each silver button assembly, mounted in the rear of the unit. The silver buttons connect to taps from the associated resistance plate.

The control element also includes two adjustable range-setting resistors connected in series with the regulator coil. These resistors are provided to set the range (covered by the voltage adjusting rheostat) so that rated generator voltage is obtained with the voltage adjusting rheostat in the midposition.

The primaries of two potential transformers, connected in open delta, are connected across the terminals of the a-c generator (fig. 4-4). The secondaries of these transformers are connected to a 3-phase, full-wave rectifier through the compensator. The d-c output of the rectifier is applied to the series circuit consisting of the regulator coil, range-setting resistance, voltage adjusting rheostat, and secondary of the damping transformer.

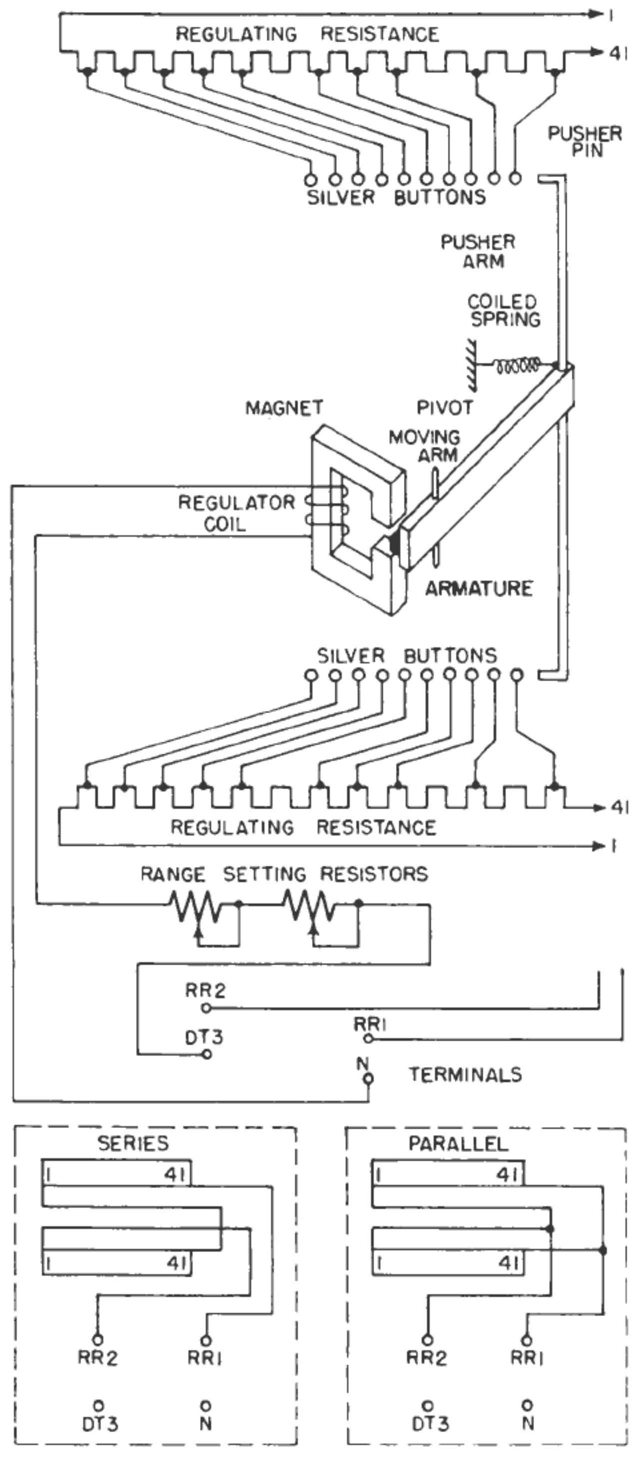


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Figure 4-5.—Control element of direct acting voltage regulator.

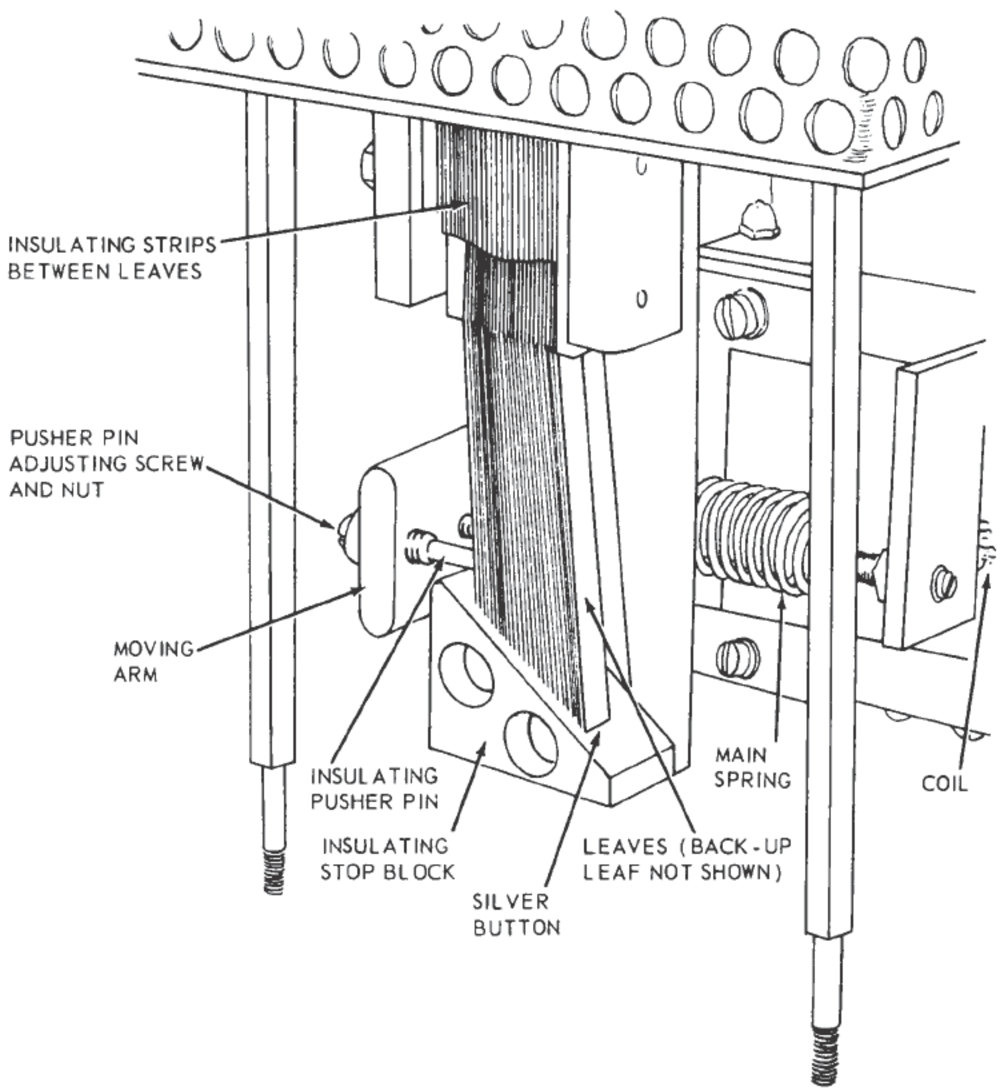

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Figure 4-6.—Silver button assembly.

When the regulator coil is energized, the magnetic pull on the iron armature is balanced against the mechanical pull of the coiled spring. If the magnetic pull of the armature overcomes the pull of the spring, all of the silver buttons are separated from each other, placing maximum resistance in the field circuit. Conversely, if the tension of the coiled spring overcomes the pull of the armature, the silver buttons are pressed together, shorting out the resistance in the field circuit. Thus, the moving arm operates through its travel, depending on the direction of motion, to successively open or close the silver bottons, which increases or decreases the resistance in the exciter field. The moving arm has a short travel so that all resistance can be inserted or cut out quickly, or it can be varied gradually, depending on the required change in excitation.

Damping Transformers

The damping transformer is an antihunt device, which consists of two windings placed on the center leg of a C-shaped laminated iron core. The primary of this transformer is

connected across the output of the exciter (fig. 4-4). When a change occurs in the exciter voltage, the primary of the damping transformer induces a voltage in its secondary. The secondary voltage acts on the regulator coil to dampen the the movement of the armature and thus prevents hunting and excessive changes in the generator terminal voltage.

For example, when the alternating voltage rises, the regulator operates because of the increasing magnetic pull on the armature. This action inserts resistance in the exciter field circuit to reduce the exciter field current and armature voltage. The primary of the damping transformer across the exciter circuit is subjected to this change in current, and through transformer action, a momentary voltage is induced in the secondary that opposes the increase in regulator coil current. This action is a form of negative feedback that lowers the magnitude of the increase in regulator coil current and thus restricts the magnitude of the decrease in exciter field current and armature voltage.

Conversely, when the alternating voltage falls, the regulator operates in the oppositie direction because of the pull exerted by the coiled spring. This action shorts out resistance in the exciter field circuit, and the impulse from the damping transformer momemtarily opposes the decrease in regulator coil current. This action reduces the extent of the decrease in regulator coil current and thus restricts the magnitude of the increase in exciter field current and armature voltage.

The voltage adjusting rheostat (fig. 4-4), as in the indirect acting voltage regulator, is used to raise or lower the regulated value of the a-c generator voltage.

The regulator control switch has three positions (normal, test, and automatic).

When the control switch is in the MANUAL position, the a-c generator voltage is controlled manually by the EXCITER FIELD rheostat (fig. 4-4).

When the control switch is in the TEST position, the control element is energized, but the regulating resistance is shorted out. The current in the exciter field circuit can be varied by the exciter field rheostat, and the operation of the moving arm in the control element can be observed.

When the control switch is in the AUTOMATIC position, the generator is under full control of the regulator, which will adjust the voltage to the value predetermined by the position of the voltage adjusting rheostat.

When operating the control switch from the MANUAL to the AUTOMATIC position, pause in the TEST position to allow the transient current in the regulator coil circuit to disappear without disturbing the a-c generator voltage. The transient current is caused by the sudden connection of the damping transformer primary across the exciter armature.

Cross-Current Compensator

The cross-current compensator (fig. 4-4) is similar to the previously described compensator used with the indirect acting voltage regulator.

Operation

When the generator circuit breaker is closed and the control switch is in the AUTOMATIC position, the generator is under control of the voltage regulator (fig. 4-4). If the a-c generator voltage is normal, the regulator moving arm is at rest in a balanced state.

If an additional load is placed on the generator, causing the terminal voltage to drop, an increase in the exciter field current is required to increase the generated voltage and to restrict the fall in terminal voltage.

The decrease in generator terminal voltage is transmitted through the 440/110-volt potential transformers and the rectifier, thus decreasing the magnetizing effect of the regulator coil. The pull of the coiled spring overcomes the magnetic pull on the armature and moves the arm in a direction to begin closing in sequence more of the silver buttons. This action shorts outs (in small steps) additional positions of the regulating resistance, which (being connected in the exciter field circuit) causes the exciter field current to be increased and the a-c generated voltage to be raised. This action prevents the terminal voltage from decreasing further. When the voltage decrease is checked, the moving arm of the regulator is again in a balanced state. The position of the regulator moving arm, however, has changed to correspond to the increase in load on the generator.

If some load is removed from the generator, causing the terminal voltage to rise, a decrease in the exciter field current is required to restore the voltage to normal. The increase in terminal voltage increases the magnetizing

effect of the regulator coil so that the magnetic pull on the armature overcomes the pull of the coiled spring and moves the arm in a direction to begin separating in sequence more of the silver buttons. This action inserts in (small steps) additional portions of the regulating resistance, which causes the exciter field current to be decreased and the a-c generated voltage to be lowered so as to restrict the rise in terminal voltage to a small value.

The silverstat voltage regulator can increase the excitation to the ceiling voltage of the exciter, or the excitation can be reduced to the lowest value required. Because the total travel of the moving arm is only a fraction of an inch, the regulating resistance can be varied in a few cycles from maximum to practically zero, depending on the requirements of the operating conditions.

To place the voltage regulator in control for the first time:

1. Be certain that the generator line circuit breaker is open.
2. Turn the regulator control switch to the MANUAL position.
3. Turn the exciter field rheostat in the direction to lower the voltage.
4. Turn the voltage adjusting rheostat to a position midway between the lower and raise ends of its travel.
5. Check to see that the brush settings are correct.
6. Bring the a-c generator and exciter up to speed.
7. Turn the exciter field rheostat gradually in the direction to raise the voltage, and at the same time, observe the a-c generator voltmeter. When the voltmeter indicates the rated a-c generator voltage, stop turning the exciter field rheostat and mark the position. This position should be rechecked later and marked for hot fields. It will be useful to mark positions on the exciter field rheostat for loads ranging from no load to full-load, rated a-c generator amperes. Then, prior to turning the regulator control switch from the AUTOMATIC to the MANUAL position, determine the correct position of the exciter field rheostat and set it for the existing a-c generator load.

To remove the regulator from control of an a-c generator, be certain that the exciter field rheostat is in the marked position corresponding to the load on the generator. Then turn the regulator control switch to the MANUAL position. The a-c generator is now under control of the exciter field rheostat.

8. To place the regulator in control of the a-c generator voltage, turn the regulator control switch from the MANUAL to the TEST position. Pause for two or three seconds and then turn the switch to the AUTOMATIC position. Then turn the voltage adjusting rheostat until the a-c generator reaches the rated value. After this condition has been obtained, the regulator moving arm should settle promptly after a load or voltage change. If the arm should swing back and forth continuously, check the polarity of the damping transformer terminals. The wrong polarity or an open circuit will cause this violent swinging.
9. When the generator voltage is approximately at rated value, close the generator circuit breaker if the generator is operating alone. If the generator is to be operated in parallel with a generator already connected to the bus, close the circuit breaker of the incoming generator only when the two voltages are in synchronism. The incoming generator can be connected to the line with the regulator control switch in the NORMAL or AUTOMATIC position.
10. As soon as the two generators are operating in parallel, readjust the governor motor (speed-changer) until each unit takes its share of the kilowatt load.

To shut down the generator, remove the load on the generator by governor adjustment while observing the wattmeter. If necessary turn the voltage adjusting rheostat in a direction to reduce the current. As the load approaches zero, open the generator line circuit breaker.

Maintenance

In addition to the manufacturer's detailed instructions given in the voltage regulator books, the following are applicable for direct acting types.

Connections must be tight and strictly in accordance with installation wiring diagrams for purposes of maintaining the effective resistance in the shunt field circuit of the exciter. The operation of the silver buttons must be smooth throughout the entire travel of the movable core.

It is well to recall information about silver contacts given in the training course, Electrician's Mate 3 & 2, NavPers 10546 (revised). Contacts made of silver or its alloys conduct current when discolored (blackened during arcing) with silver oxide. This blackened condition,

therefore, requires no filing, polishing, or removing.

ROTARY AMPLIFIER VOLTAGE REGULATOR

The rotary amplifier (amplidyne) type of voltage regulator utilizes a special type of exciter that furnishes a large change in output voltage for a small change in the control field current of the exciter. The control element detects the variation of the a-c generator voltage from a reference voltage, which can be set to a predetermined value. The variation between the actual alternating voltage and the reference voltage sends a current through the control field of the exciter to change its output voltage, and hence change the a-c generator field current to hold the alternating voltage at the desired value.

The complete amplidyne voltage regulator equipment consists of (1) amplidyne exciter, (2) pilot alternator, (3) stabilizer, (4) voltage adjusting units (5) automatic control unit, (6) manual control unit, and (7) potential unit as illustrated by the block diagram in figure 4-7. Some installations include two normal voltage regulators and one standby regulator for two a-c generators.

A cutout switch, with two positions (manual and automatic) is provided for each generator. This switch is used to connect the amplidyne exciter and the regulator for either manual or automatic control of the a-c generator voltage.

A transfer switch with three positions (normal, gen A, and gen B) is provided to permit substituting the standby voltage regulator for either of the two normal regulators.

In the NORMAL position, generators A and B are connected in the normal automatic voltage control circuits of their respective regulators, and the standby regulator is disconnected.

In the GEN A position, the standby regulator has taken control from the normal regulator of generator A, and generator B is connected to its normal regulator.

In the GEN B position, the standby regulator has taken control from the normal regulator of generator B, and generator A is connected to its normal regulator.

Amplidyne Exciter

The amplidyne exciter (fig. 4-7) is a rotary amplifier that responds quickly to small changes in control field current to cause large changes in output. It is mounted on the shaft of the prime mover and provides the excitation for the a-c generator. The principles of the amplidyne exciter are explained in the training course, Basic Electricity, NavPers 10086 (revised).

Voltage Adjusting Unit

The voltage adjusting unit is provided to establish the a-c generator voltage that the regulator will maintain. This unit (fig. 4-8) consists of a tap switch and tapped saturated reactor designed for mounting directly behind the generator control panel with the handle of the tap switch on the front of the panel. The saturated reactor is the main component of the voltage adjusting unit and the heart of the regulator system.

The saturated reactor determines the a-c generator voltage, which the regulator will maintain. It consists of a tapped coil of approximately 400 turns wound on a soft iron core. The core is operated in the saturated region so that a very small change in the applied voltage and flux density will produce a large change in coil current.

Changing the taps on the coil changes the reactance of the coil circuit and the voltage level held by the regulator. Increasing the turns (to a higher tap number) increases the reactance and voltage required to maintain a given coil current. Conversely, decreasing the turns decreases the reactance and voltage required to maintain the current. Tap changing is only performed on the original installation or on overhaul.

Pilot Alternator

A voltage regulator requires a "reference" or standard to which the voltage being regulated may be compared to determine whether or not the regulator should act to change the excitation of the a-c generator. In the previously described direct acting voltage regulator this reference is provided by a coiled spring. In the amplidyne voltage regulator the reference is provided by a "boost" current of approximately 0.5 ampere from the pilot alternator. The pilot alternator (fig. 4-7) is a small permanent-magnet, single-phase, a-c generator mounted on an extension of the amplidyne shaft. The output effective voltage of the pilot alternator is essentially constant.

Potential Unit

The potential unit (fig. 4-7) contains a potential transformer and a potentiometer rheostat. The purpose of the potential unit is to

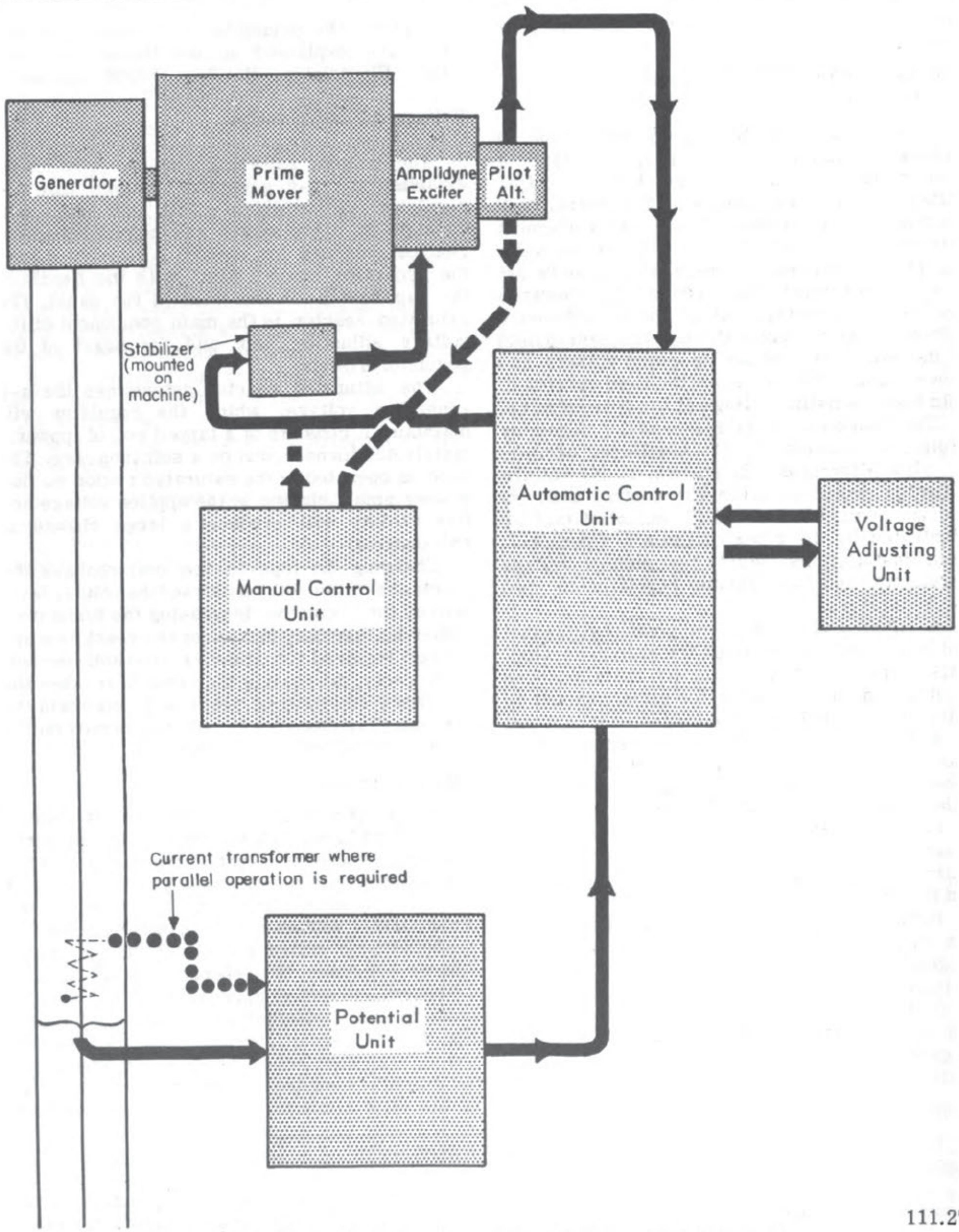

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Figure 4-7.—Block diagram of amplidyne voltage regulator system.

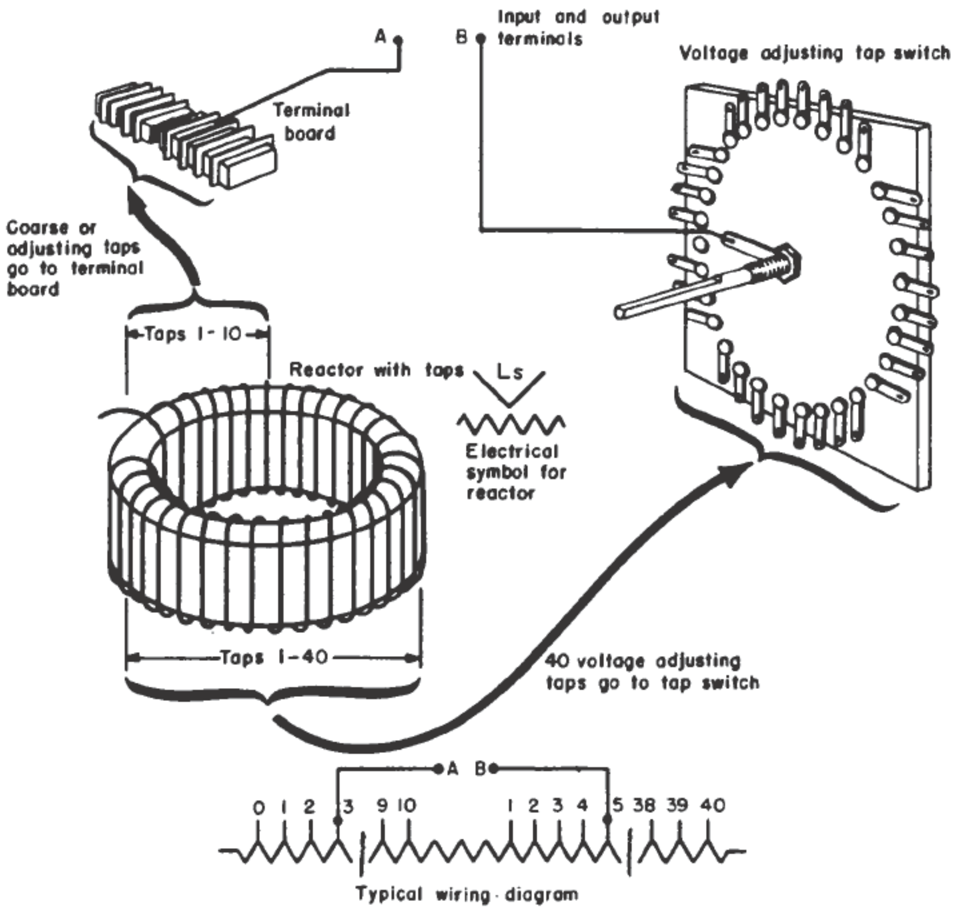

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Figure 4-8.—Voltage adjusting unit.

provide a signal voltage to the regulator proportional to the voltage of the a-c generator. The potential transformer is a special T-connected, 450-volt transformer.

The potentiometer rheostat is connected in the circuit of a current transformer and is used to provide the reactive load division between generators operating in parallel. The potential unit is designed for mounting inside the generator switchboard near the current transformer and the generator circuit breaker.

Automatic Control Unit

The automatic control unit (fig. 4-7) contains the static elements that are required for automatic voltage control. Part of the control-unit circuit makes the voltage regulator responsive to the average of the 3-phase voltages of the generator. Also, a frequency compensating network permits the regulator to hold the a-c generator voltage practically constant, regardless of changes in the generator frequency, from 57 to 63 cycles. The automatic control unit is designed for mounting inside the generator control switchboard.

Stabilizer

The stabilizer (fig. 4-7) is mounted on or near the amplidyne exciter and prevents sustained oscillation of the generator. It is essentially a transformer, but because it is in a d-c

circuit, the stabilizer functions only when there is a change in the exciter voltage, which is impressed across its primary. The secondary winding is connected in series with the control field of the amplidyne exciter.

When the regulator operates to change the exciter voltage, a voltage is induced in the control field circuit through the stabilizer. This momentarily affects the control field current to restrain the regulator from making excessive correction of the exciter voltage, thereby preventing hunting.

Manual Control Unit

The manual control unit (fig. 4-7) is provided to control the voltage of the generator when the automatic control equipment is not in use. This unit consists of two resistor plates and a single-phase full-wave rectifier. The two resistor plates are connected as a rheostat and a potentiometer, which operate concentrically. The manual control unit is mounted inside the switchboard with the operating handwheels protruding through on the front of the panel. The large handwheel provides for coarse voltage adjustment, and the small handwheel is used for fine or vernier adjustment.

Automatic Control Circuit

An elementary diagram of the automatic control circuit is illustrated in figure 4-9. The circuit consists of a buck circuit shown in heavy lines and a boost circuit shown in light lines. The a-c portions of the circuit are indicated by double-headed arrows and the d-c portions by single-headed arrows. The saturated reactor, Ls, is energized from the a-c generator voltage that is to be regulated and is connected to rectifier, CR1. The pilot alternator feeds rectifier, CR2. The amplidyne control field, F1F2, is connected across the output of CR1 and CR2.

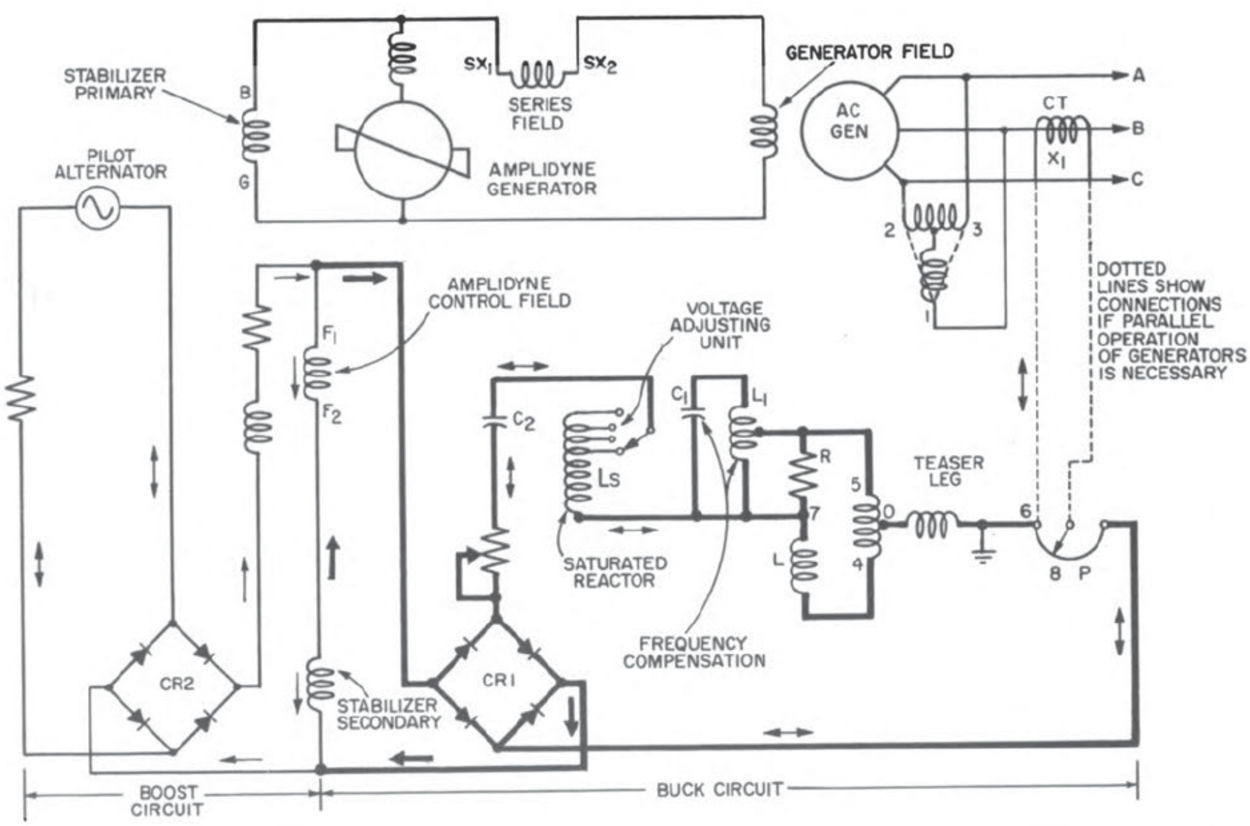

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Figure 4-9.—Automatic control circuit.

The amplidyne exciter supplies the a-c generator field directly.

The voltage from the pilot alternator tries to force (conventional) current through the amplidyne control field in such a direction (from F1 to F2) that the amplidyne will boost the a-c generator voltage. The saturated reactor circuit tries to force current through the control field in the opposite direction (from F2 to F1), tending to decrease the generator voltage. When the a-c generator voltage is near normal, the regulator is at its normal operating point and the boost current supplied by the pilot alternator is in the opposite direction and nearly equal to the buck current supplied by the saturated reactor circuit. Thus, the current through the control field is negligible, and the amplidyne excitation is provided by the series field of the amplidyne to maintain normal terminal voltage of the a-c generator.

However, if the generator voltage should drop slightly below normal, the buck current supplied by the saturated reactor would drop considerably. This action causes a boost current to flow in the control field, which tends to raise the a-c generated voltage and thus prevents the terminal voltage from decreasing further. This action occurs because the pilot alternator is not affected by the generator voltage and is still trying to force a boost current through the control field.

If the generator voltage should increase slightly above normal, the saturated reactor circuit would pass a large additional current through the amplidyne control field, tending to buck or decrease the a-c generated voltage and prevent the terminal voltage from any further increase.

Three-Phase Response Circuit

The 3-phase response circuit (fig. 4-10) consists of (1) a T-connected potential transformer, (2) a resistor, R, and (3) an inductor, L. The resistance and inductance are in series across one secondary winding of the potential transformer (fig. 4-10A). When a balanced 3-phase voltage is impressed on the primary, 1-2-3, a voltage, 4-5-6, appears across the secondary. The voltages across the inductor, L, and the resistor, R, are 4-7 and 7-5, respectively (fig. 4-10B). The relationship of these voltages is 4-7-5, giving a resultant voltage, 7-0, in phase with and added to the voltage, 0-6.

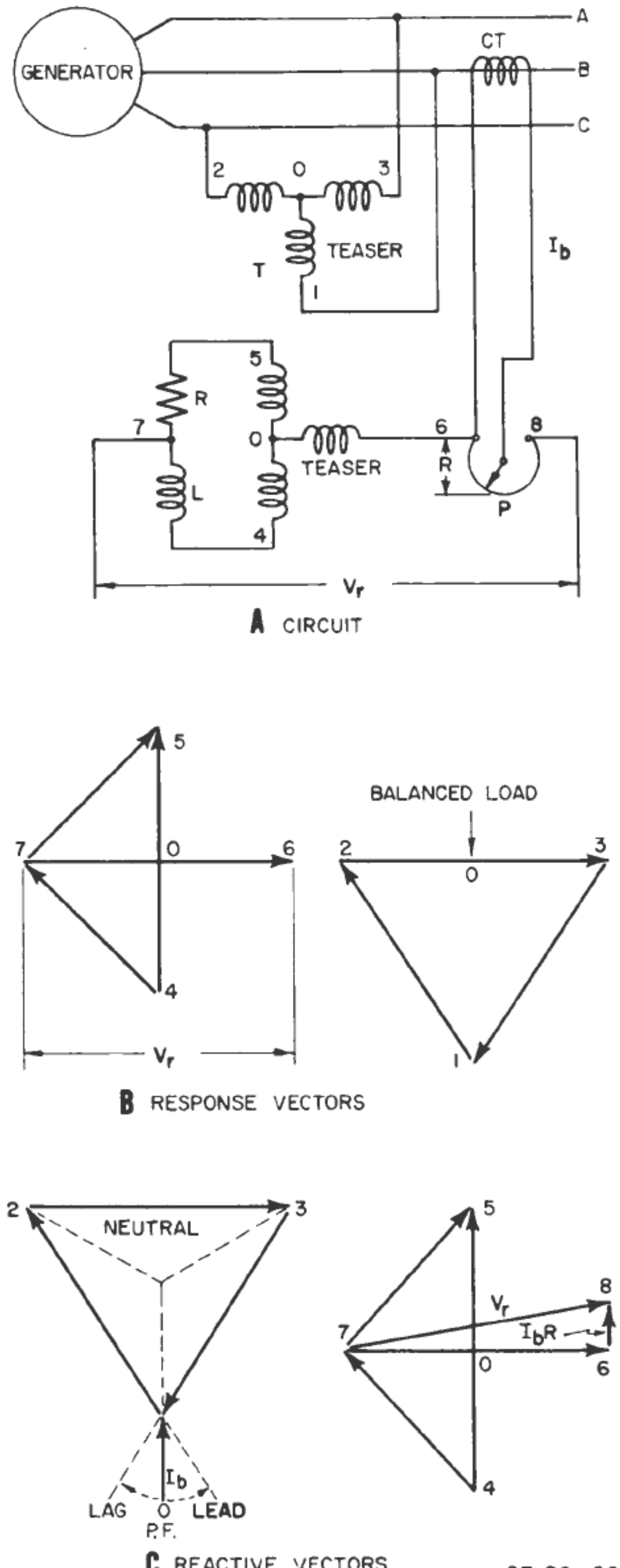

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Figure 4-10.—Three-phase response circuit.

The resulting voltage, 7-0-6 (V_r) is the voltage of the network used to energize the regulator circuits. The regulator at constant frequency will always act to maintain voltage V_r constant. If there is any deviation in generator voltage from its normal value, the system will make corrections until the 3-phase voltages, 1-2-3, are the values that will produce normal voltage V_r.

The correct phase sequence of the connections of the potential unit to the generator leads is essential to the correct functioning of this network. If the connections are reversed, for example, by interchanging the two leads from the secondary teaser winding, the voltage, 7-0, would be subtracted from the voltage, 0-6, instead of added to it. The voltage, V_r, impressed on the regulator would then be approximately one-fifth the required value. Thus, the regulator in attempting to go to the ceiling voltage would overexcite the generator to abnormal levels.

Frequency Compensation

The reactance of the saturated reactor (fig. 4-9) increases as the frequency increases. Thus, an increase in frequency from 60 to 63 cycles per second at normal 100 percent voltage would decrease the buck current, and the boost current would predominate so that the regulator would tend to hold a higher voltage. A frequency lower than 60 cycles per second would have the opposite effect, tending to increase the buck current so that it would predominate, and the regulator would tend to hold a lower voltage.

Therefore, a voltage regulator system utilizing a saturated reactor must be provided with a means of compensating for the effect of frequency changes. Frequency compensation is provided by the addition of an inductor, L1, and a capacitor, C1, in parallel with each other and across the resistance portion of the positive phase sequence network used for 3-phase response (fig. 4-9). The values of the inductor and capacitor are such that at the normal frequency of 60 cycles they provide a resonant parallel circuit, which acts like a high resistance. The other components of the system are adjusted so that this resistance has no effect on the action of the regulator at normal frequency.

When the frequency increases above 60 cycles, the parallel circuit has a capacitive effect, which raises the apparent voltage "seen" by the saturated reactor and causes it to pass as much buck current on normal voltage at the higher frequency as at normal frequency.

When the frequency decreases below 60 cycles, the parallel circuit acts more like an inductance, which lowers the apparent voltage as "seen" by the saturated reactor and causes it to pass no more buck current on normal voltages at the lower frequency than it would at normal frequency. Thus, the parallel circuit compensates for the frequency effect on the saturated reactor, and it passes the same buck current at a particular line voltage at any frequency between 57 and 63 cycles.

Reactive Compensation

When a-c generators are operated in parallel, the division of the kw load between machines is a function of the governors of the prime movers. The division of the reactive kva is a function of the regulators, which increase or decrease the excitation of the generators.

The division of the reactive kva between generators (when operated in parallel) is accomplished by a compensating potentiometer rheostat, P, and a current transformer, CT, provided for each machine (fig. 4-10A). The rheostat is connected in series with the TEASER leg of the T-connected potential transformer secondary. The current transformer is connected in the B phase of the generator with its secondary connected across one side of the potentiometer rheostat.

The generator voltage, 1-2-3, feeds the primary of the T-connected potential transformer (fig. 4-10A). The line current, I_b, of phase B in which the current transformer is connected, is in phase with the line-to-neutral voltage, at unity power factor, and I_b is at 90° to the voltage, 2-3 (fig. 4-10C). At any other power factor, current I_b swings out of phase with the line-to-neutral voltage for lag or lead conditions.

The secondary voltage, 7-6 (fig. 4-10B), which is the resultant output voltage of the 3-phase response network, is in phase with the line voltage, 2-3, and is the voltage, V_r impressed on the saturated reactor. At unity power factor, current I_b produces a voltage, 6-8, across the compensating rheostat, P, which is 90° out-of-phase with voltage 7-6 (fig. 4-10C). The voltage, 6-8 (I_bR) is the compensating voltage. The voltage, 7-8 (V_r) is now impressed on the saturated reactor, and the regulator tends to hold the voltage proportional to 7-8.

When two duplicate generators, A and B, are operating in parallel at rated power factor, the

line currents, I, will be equal and the voltage 7-8 (V_r), "seen" by the saturated reactors of both regulators will also be equal if the field currents are balanced (made equal), the compensating rheostats set at the same value of resistance, and the governors set for equal division of kw load. Assume that a reactive load is placed on the system and that an instantaneous unbalance occurs with generator A having a weaker field and generator B having a stronger field. This unbalance can be due to slight differences in the reactances or saturation characteristics of the generators or in the characteristics of the regulators. Because the excitation is unbalanced, there is a circulating current between the two generators and their power factors are unbalanced.

The effect of this unbalance distorts the voltage triangle, 7-6-8 (fig. 4-10C), and the network voltage, 7-6, decreases slightly due to the drop in line voltage. The compensating voltage, 6-8 (I_bR) from the current transformer and the compensating rheostat have changed due to the unbalanced line currents and power factors. Therefore, the compensating voltage 6-8 for generator B is greater and at a different phase angle than the corresponding voltage for generator A. Thus, the resultant voltage 7-8 (V_r) of the two machines is unequal and different from the original voltage that the regulators were set to hold constant.

The regulators will act to change the excitation of the two generators to restore the voltage, 7-8, to equal the value, V_r, for which they are set by changing the values of the field currents so that they are balanced. The line currents and power factors will then be approximately balanced to give equal compensating voltages 7-8, so that these voltages "seen" by the regulators for generators A and B, respectively, will be equal to each other.

The regulator holds voltage V_r constant, and the voltage, 7-6, depends on the value and phase angle of the compensating voltage, 6-8. The network voltage, 7-6, which is the difference between V_r and 6-8 and is proportional to the line voltage, has decreased slightly due to this change, and thus the line voltage will be slightly less than was maintained before the change occurred on the system. This drop in line voltage, resulting from an increase in load, is the DROOP from which the individual compensation type of reactive compensation is derived.

Manual Control Circuit

An elementary diagram of the manual control circuit is illustrated in figure 4-11. The buck and boost circuits are indicated by heavy and light lines, respectively. By changing the setting of the manual control rheostats the voltage that the amplidyne exciter will maintain across its terminals can be adjusted. Thus, the a-c generator terminal voltage can be varied. The manual control circuit is designed so that for any one setting of the manual control rheostat the amplidyne terminal voltage applied to the generator field will remain constant.

Operation

The schematic diagram of an amplidyne voltage regulator installation is illustrated in figure 4-12.

For normal operation of a single generator the following sequence of steps should be performed:

1. Be certain that the generator circuit breaker is open.
2. Set both handwheels of the manual control unit in the extreme LOWER position, turn the regulator cutout switch to MANUAL, and turn the transfer switch to NORMAL.
3. Start the prime mover and bring the generator up to speed.
4. Raise the generator voltage to approximately 450 volts by turning the handwheels of the manual control unit in the RAISE direction.
5. Set the handle of the voltage adjusting unit for 450 volts corresponding to no load.
6. Turn the cutout switch from MANUAL to AUTOMATIC.
7. The regulator is now in control of the a-c generator voltage. Adjust the generator voltage to 450 volts by turning the handle of the voltage adjusting unit.
8. Close the generator circuit breaker. If the generator is to be operated in parallel with a generator already connected to the bus, close the circuit breaker of the incoming generator only when the two voltages are in synchronism.
9. As soon as the two generators are operating in parallel, readjust the governors of the prime movers until each unit takes its share of the kw load.
10. Equalize the power factors of the machines by means of the voltage adjusting units. If the power factor of one generator is leading and that of the other is lagging, correct this

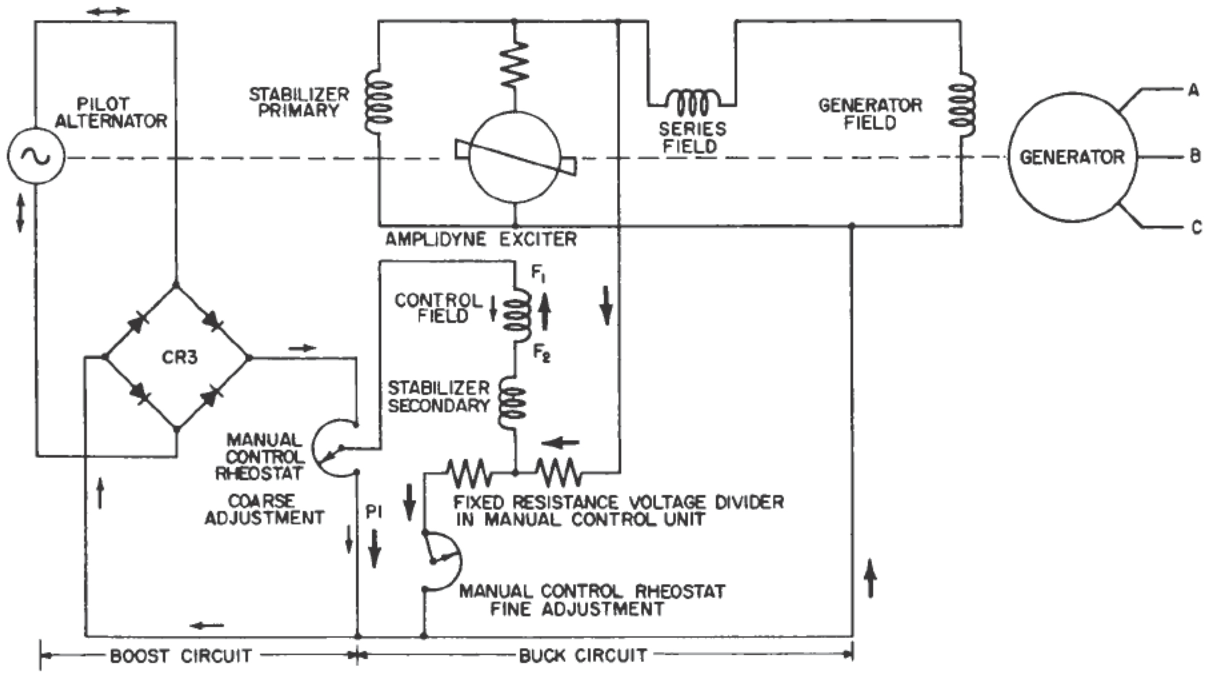

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Figure 4-11.—Manual control circuit.

condition by slightly turning the voltage adjusting unit of the generator with the leading power factor in the raise direction, and the voltage adjusting unit of the other generator slightly in the lower direction. When the kw loads and power factors on the generators are equal, the current on each generator should also be equal.

11. If the system voltage is high after the power factors are balanced, slowly turn the voltage adjusting units of both generators in the lower direction until the system voltage is approximately 450 volts.

12. If the system voltage is low, slowly turn the voltage adjusting unit of both generators in the raise direction until the system voltage is approximately 450 volts.

To remove the regulator from control of an a-c generator:

1. Check to see that the manual control unit is set to the mark for 450 volts corresponding to no load.

2. Turn the cutout switch from the AUTOMATIC to the MANUAL position.

3. Remove the load on the generator by governor adjustment while observing the wattmeter. Turn the manual control unit in the lower direction until the ammeter reads zero. Then open the generator line circuit breaker.

Maintenance

The maintenance instructions for a specific rotary amplifier regulator given in the manufacturer's manual shall take precedence over other procedures. However, the articles concerning care of rotating electrical machinery in chapter 61 of BuShips Technical Manual shall be observed in all cases where they do not conflict with the manufacturer's instructions.

The amplidyne's short-circuiting brushes should be checked periodically, as improper brush contact may result in an excessively high amplidyne voltage output.

STATIC EXCITATION AND VOLTAGE REGULATION SYSTEM

The static excitation voltage regulator system furnishes the a-c generator field current by rectifying a part of the a-c generator output. After the a-c generator has built up some output

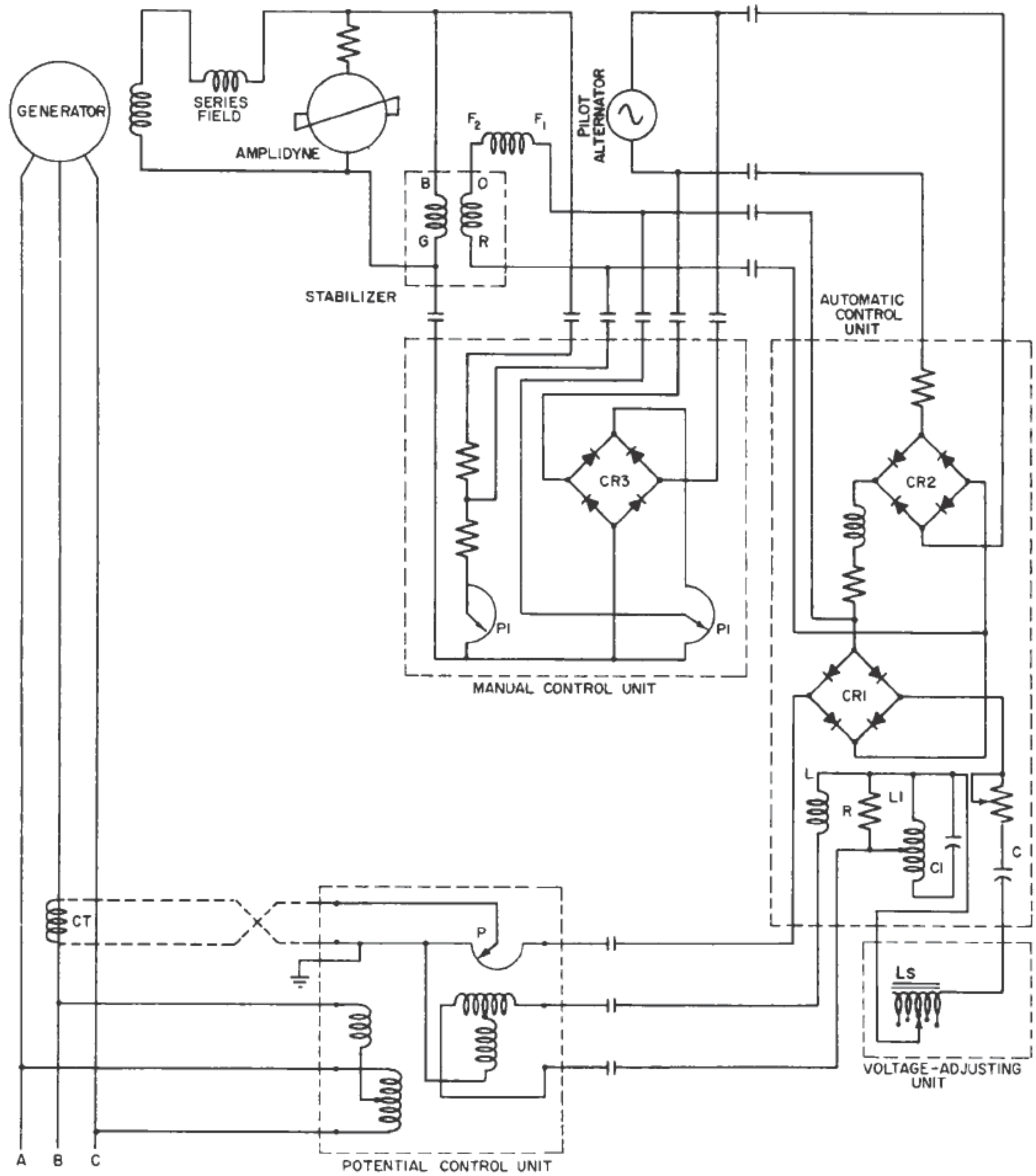

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Figure 4-12.—Schematic diagram of amplidyne voltage regulator installation.

with the aid of d-c switched temporarily to the field from a field flashing power source such as d-c generator or battery, an automatic voltage regulator controls the output of a static exciter to supply the necessary field current.

The schematic of a static excitation and magnetic amplifier type voltage regulator system is illustrated in figure 4-13. The system provides field excitation and manual and automatic control for 350 or 500-kw, 450-volt, 3-phase, 60-cycle generators.

The control switch (S1 in fig. 4-13B) has three positions (OFF, MANUAL, and AUTOMATIC). The setting of this switch determines the type of operation to be used. The OFF position can be used to quickly deenergize the generator in case of an emergency. With the switch in this OFF position, four sets of contacts (contact sets P, Q, R, and S) are closed. Contacts P, Q, and R thereby "short circuit" the potential winding of three potential transformers, respectively identified as T1, T2, and T3 in figure 4-13A to remove rectified current from the exciter. Concurrently, S contact (upper right, Fig. 4-13A) functions to trip the main breaker.

An analysis of the contact arrangement (fig. 4-13B) in switch S1 shows 64 contact-elements are placed (four per pole) on 16 poles. The first four poles produce 8 single-pole-single-throw switches (each SPST identified by 8 letters, A thru H). These 8 have 12 terminals (identified further by 12 numbers, 1 thru 12).

The fifth pole (No. 5 in fig. 4-13B) has only two numbered terminals (13 and 14) to identify switch I, where its two SPST switches are arranged in series. The function of this series arrangement is twofold: First, to provide several contacts that open fast and wide for quickly quenching the several arcs produced (in an inductive-reactance circuit) during the OFF "break" of the switching action. Second, to provide optimum cooling of heated contacts that become hot from arcing.

Each (eleven) remaining pole of switch S1 also is arranged with series assemblies like switch I. They are identified by letters J through T, with their terminals numbered 15 through 36. Switch T is a spare. The letter "x" denotes those contacts which are closed when the switch is put into a selected position of OFF, MANUAL, or AUTOMATIC.

Switch S2 is an assembly of 16 contact elements (fig. 4-13C) which are connected in series, to produce 8 switches, which operate simultaneously to function as a single ON-OFF device. Again, the function (of using many switches) serves to break a long arc into several smaller arcs for producing long life from several heat-dissipating contacts.

STATIC EXCITER

The static exciter (fig. 4-14) consists of a 3-phase rectifier, CR1, three linear inductors, L1, L2, L3, and three transformers T1, T2, T3. The transformers are alike, and interchangeable. Each transformer contains 4 windings but figure 4-14 shows only the two windings that perform in the basic exciter circuits; one is the potential or PRIMARY (P2) winding, the other the SECONDARY (S2) winding. The remaining CURRENT and control windings are discussed later. Briefly, each transformer is identified as an SCPT (saturable current potential transformer).

The PRIMARY circuits of T1, T2, and T3 are Y-connected through the linear inductors L1, and L2 and L3 by conductors 13, 23, 14 and 15.

The secondary circuits are delta connected to diodes (A, B, C, D, E, and F) of rectifier CR1 by means of conductors 16, 17, and 18. These elements comprise a 3Ø full-wave bridge rectifier that delivers d-c to conductors No. 11 and No. 9 which supply the generator field.

The current in the control windings CW1, CW2, and CW3 (fig. 4-13) controls the output of the SCPT secondaries and thus the output of the static exciter. The control windings are supplied by the voltage regulator output as discussed later. Load current flowing in the current windings (I1, I2, and I3, fig. 4-13) adds a component to compensate for the synchronous reactance drop in the generator.

Field Flashing Circuit

Since the static exciter cannot supply field current until some a-c voltage has built up in the 350 or 500 kw generator, d-c power is temporarily provided by a 50-kw d-c generator delivering 120 volts. This d-c generator also provides power for other electrical equipment on board ship.

To start the system the spring-return field flashing switch, S2, (fig. 4-13C) should be moved to the FLASH position. The control switch, S1, may be placed in either the MANUAL or AUTOMATIC position. This allows flashing

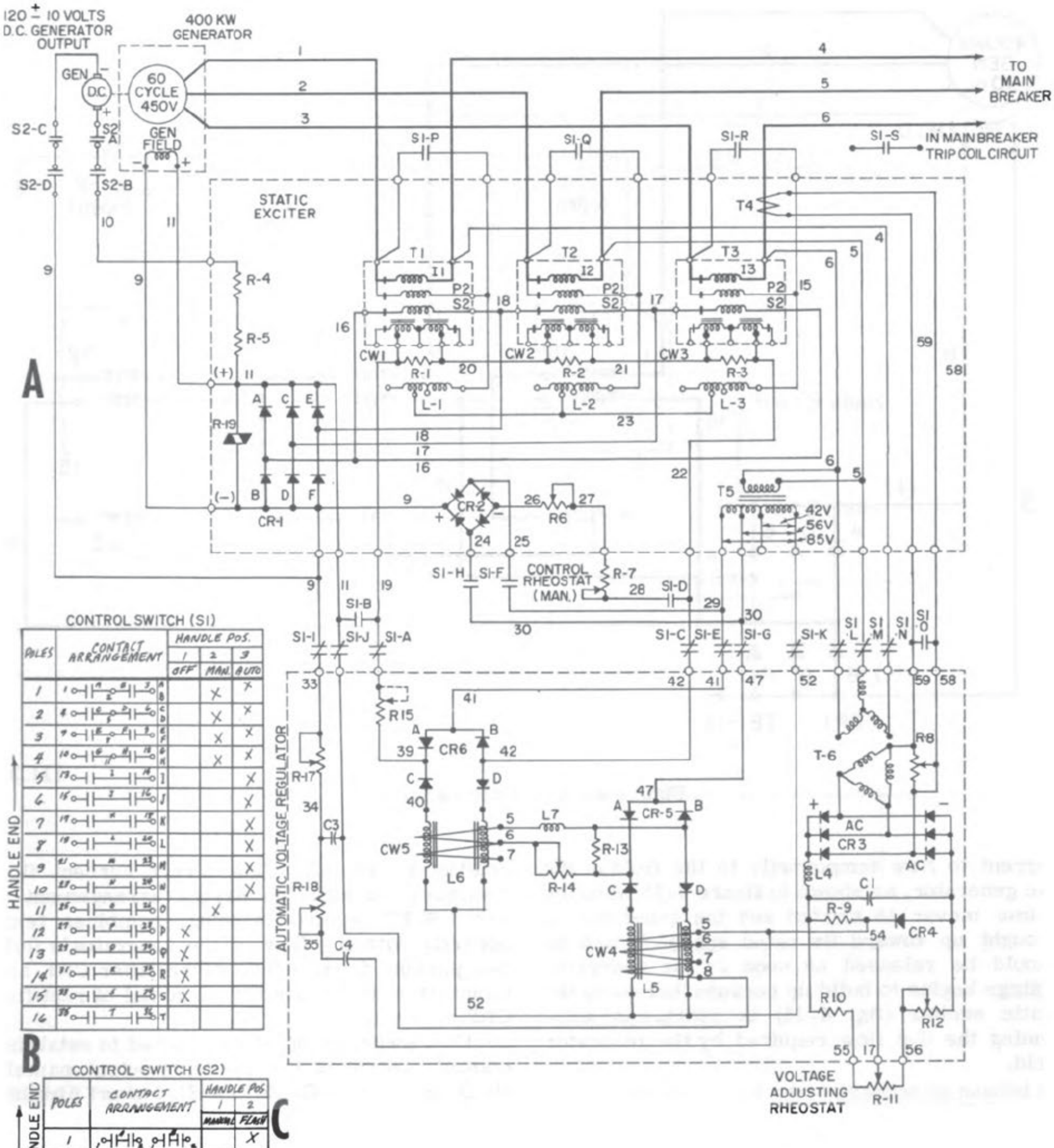

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Figure 4-13.—A. Elementary diagram of the system.
B. Control switch S1 contact arrangement.
C. Control switch S2 contact arrangement.

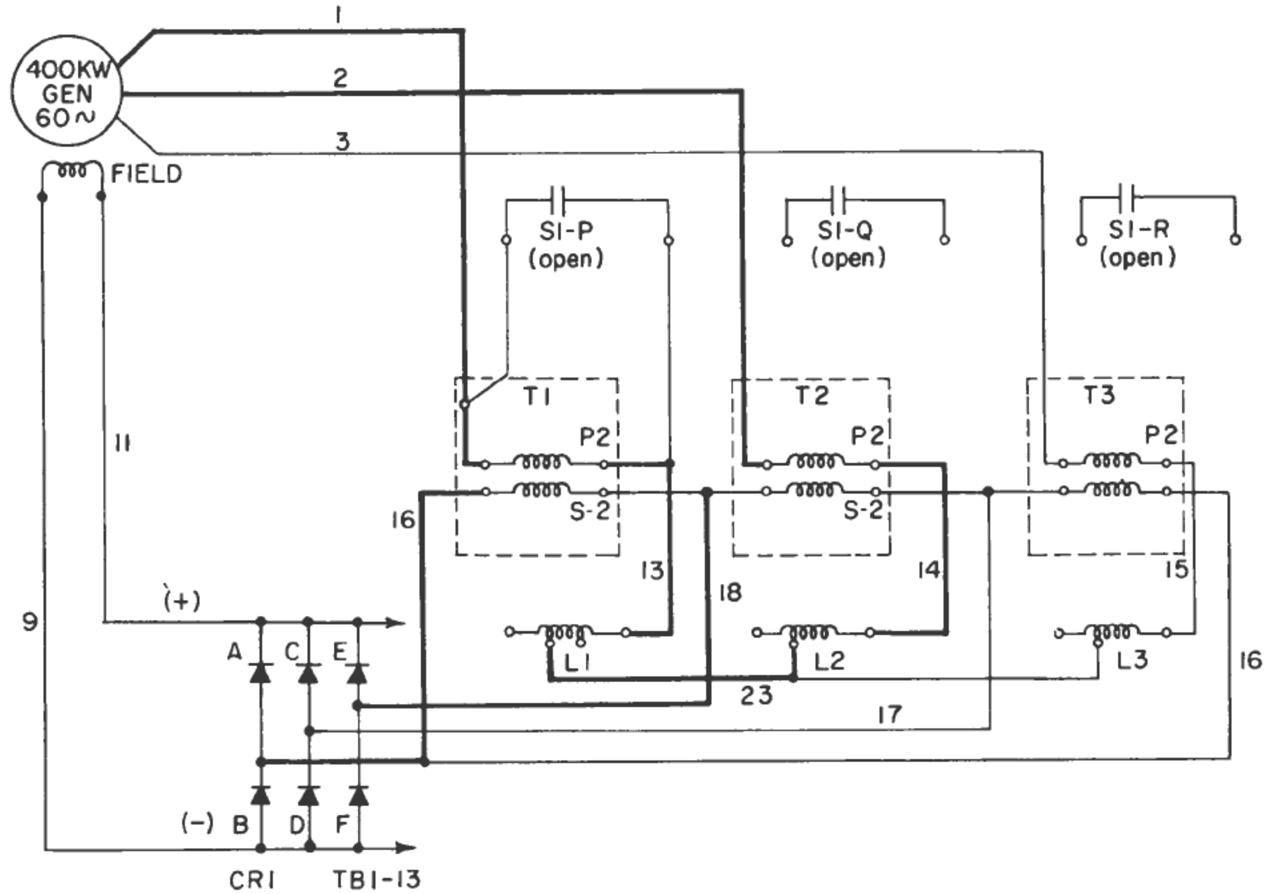

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Figure 4-14.—Static exciter.

current to flow temporarily to the field of the a-c generator, as shown in figure 4-15 when the prime mover is started and the generator is brought up toward its rated speed. Switch S2 should be released as soon as the generator voltage begins to build up because thereafter the static exciter (fig. 4-14) is capable of continuing the d-c flow required by the generator field.

Manual Voltage Control Circuit

With switch S1 (fig. 4-16) in the manual position, contacts F and H are closed connecting the 29 volt secondary of transformer T5 to the bridge rectifier CR2. The resulting d-c leaves CR2 from its negative terminal, flows by way of resistor R6 and manual control R7 and enters conductor No. 22. This direct current flow continues through the series arrangement of each SCPT control winding, combines temporarily with the flow of the generator's field d-c passing from + to - of rectifier CR1, and terminates at the positive terminal of rectifier CR2.

Five switches of S1 are closed to establish manual control of the exciter's output: namely B, D, F, H, and O. Switch S1-0 short circuits the output of transformer T4, to eliminate a drooping characteristic which is not now required. Manual operation is achieved by regulating resistor R7, which functions to vary the saturation of the cores of T1, T2, and T3. Varying the amount of direct current alters the core saturation and those variations will change the voltage value that is induced from each

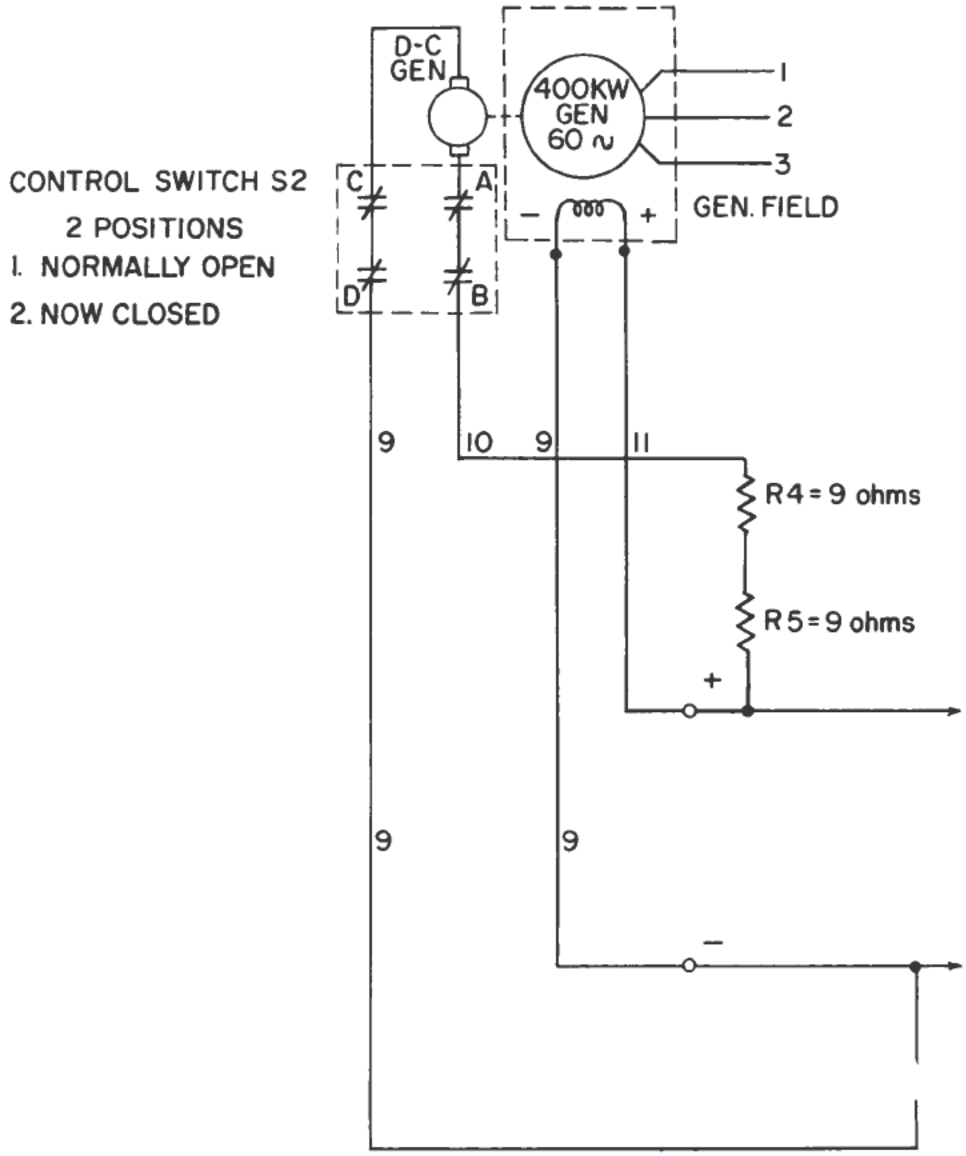

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Figure 4-15.—Field flashing circuit.

PRIMARY into its associated SECONDARY winding shown in figure 4-14.

AUTOMATIC VOLTAGE REGULATOR

The static exciter alone (fig. 4-14) will not maintain the different amounts of field current required to maintain a constant value of a-c voltage at the generator terminals during various load changes.

Therefore, a voltage regulator is needed to hold the generator voltage constant regardless of all changing conditions that tend to alter its uniformity. The automatic regulator controls the exciter output by regulating precisely the flow of d-c in the control winding of each SCPT (fig. 4-17). Here the initial a-c is provided by the 85-volt secondary of transformer T5, which feeds rectifier CR6, to provide the d-c source

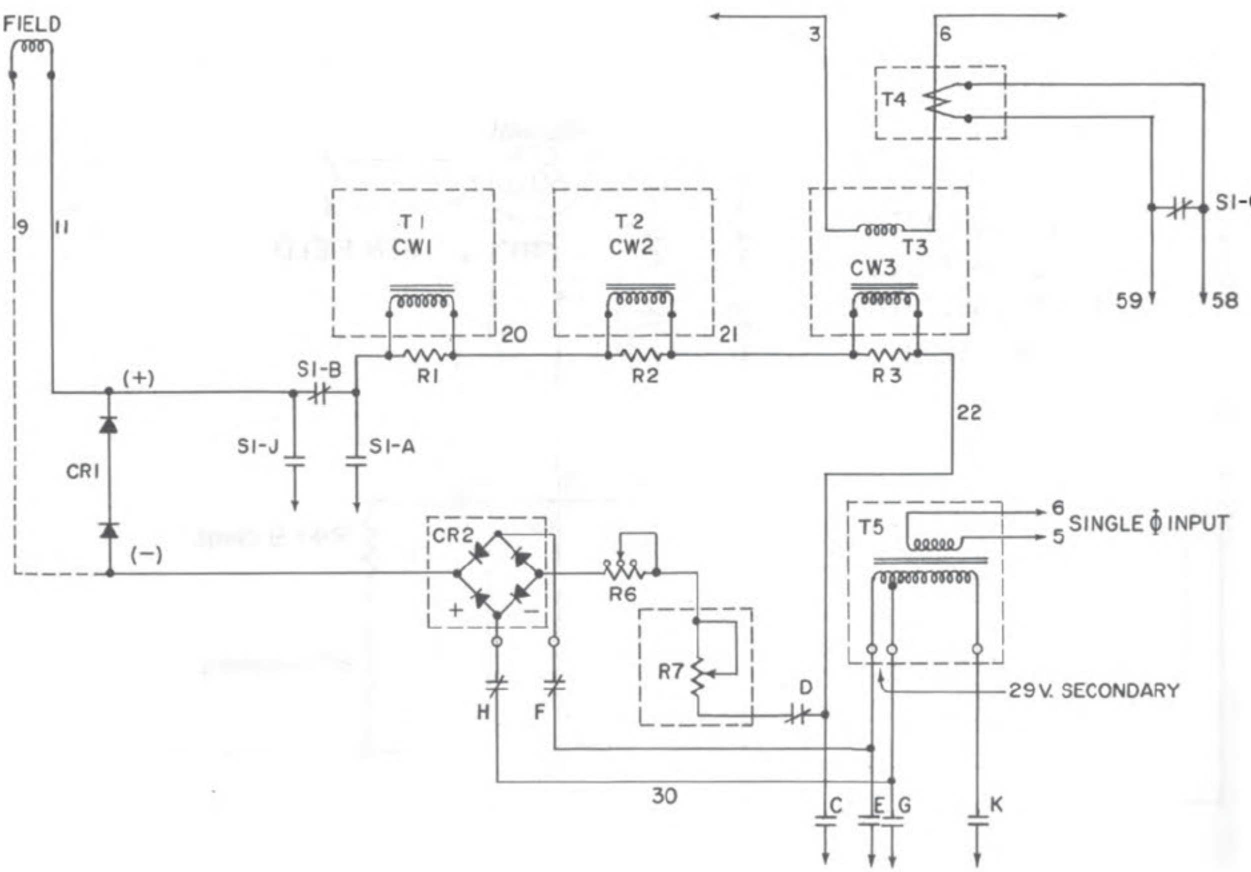

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Figure 4-16.—Manual voltage control circuits.

at terminals 39 and 42. The flow of d-c is precisely controlled by the ohmic reactance values of each coil of L6. The controlled reactance depends upon the state of magnetic saturation produced by another regulated d-c flow from rectifier CR5 (fig. 4-13).

The control of this regulated output of rectifier CR5 originates with sampling the average of the three line voltages by the sensing circuit in figure 4-18A. This voltage is processed further in the reference and comparison circuits for amplification in the pre-amplifier of figure 4-19.

Sensing Circuit

To obtain the best regulation during unbalanced load conditions in the three phases, the sensing circuit (fig. 4-18) is used which responds to the average of the three values of a-c line voltages.

Transformer T6 reduces the line voltage of each phase to a convenient value and rectifier CR3 converts the 3-phase a-c to a d-c voltage. If an unbalanced condition causes the three line voltages to become unequal, the d-c across the rectifier will have considerable (third harmonic) ripple, but the combined filter actions of inductor L4 and capacitor C1 will remove the ripple and produce d-c across C1 (near 50 volts) which is always in proportion to the average of the three line voltages.

Resistor R8 is used for reactive droop compensation and will be discussed later.

Reference Circuit

The reference circuit (fig. 4-18B) consists of resistor R9 and rectifier CR4. The function of CR4 is to supply a nearly constant (25-volt) reference voltage to the comparison circuit.

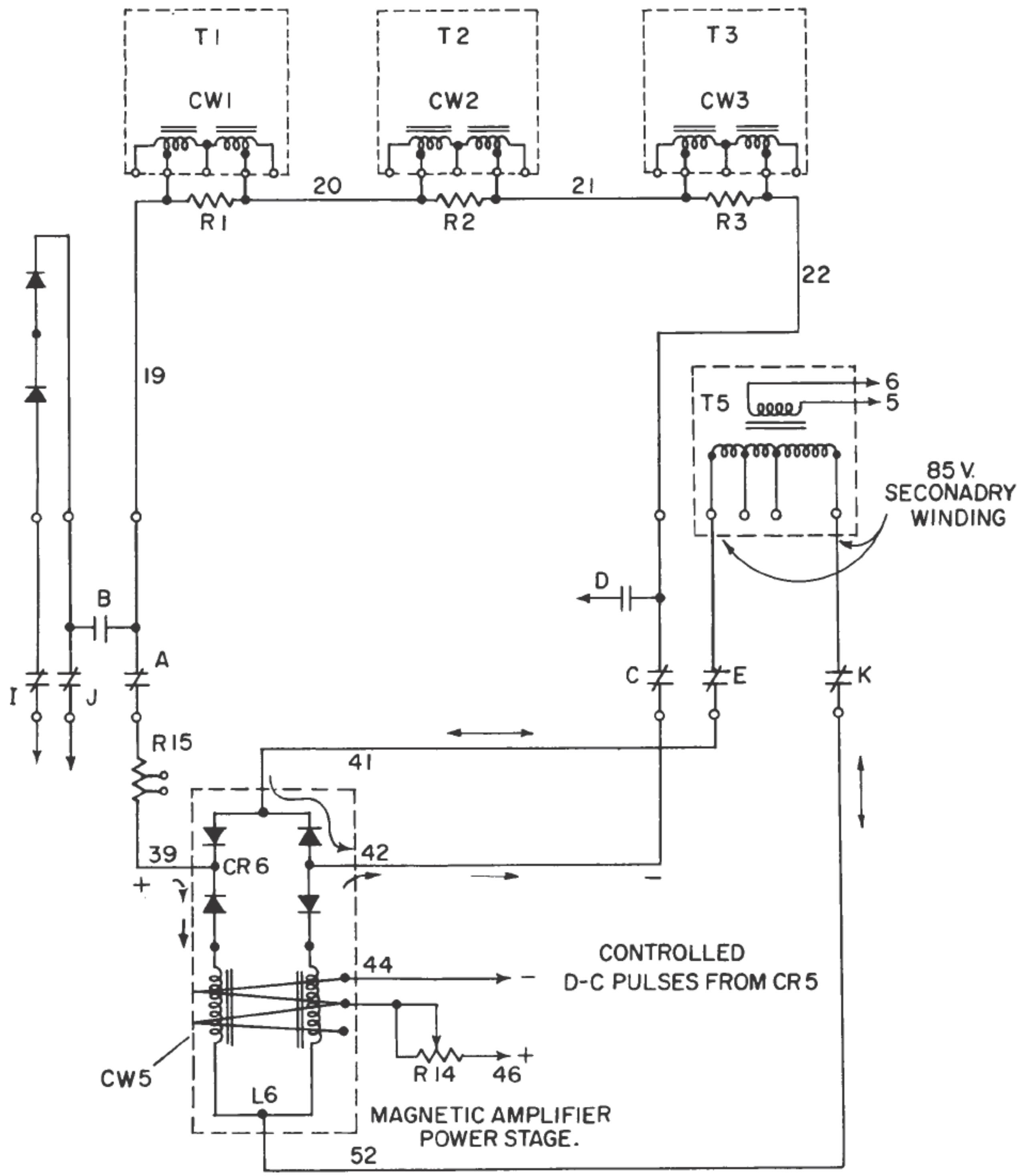

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Figure 4-17.—Final stage magnetic amplifier.

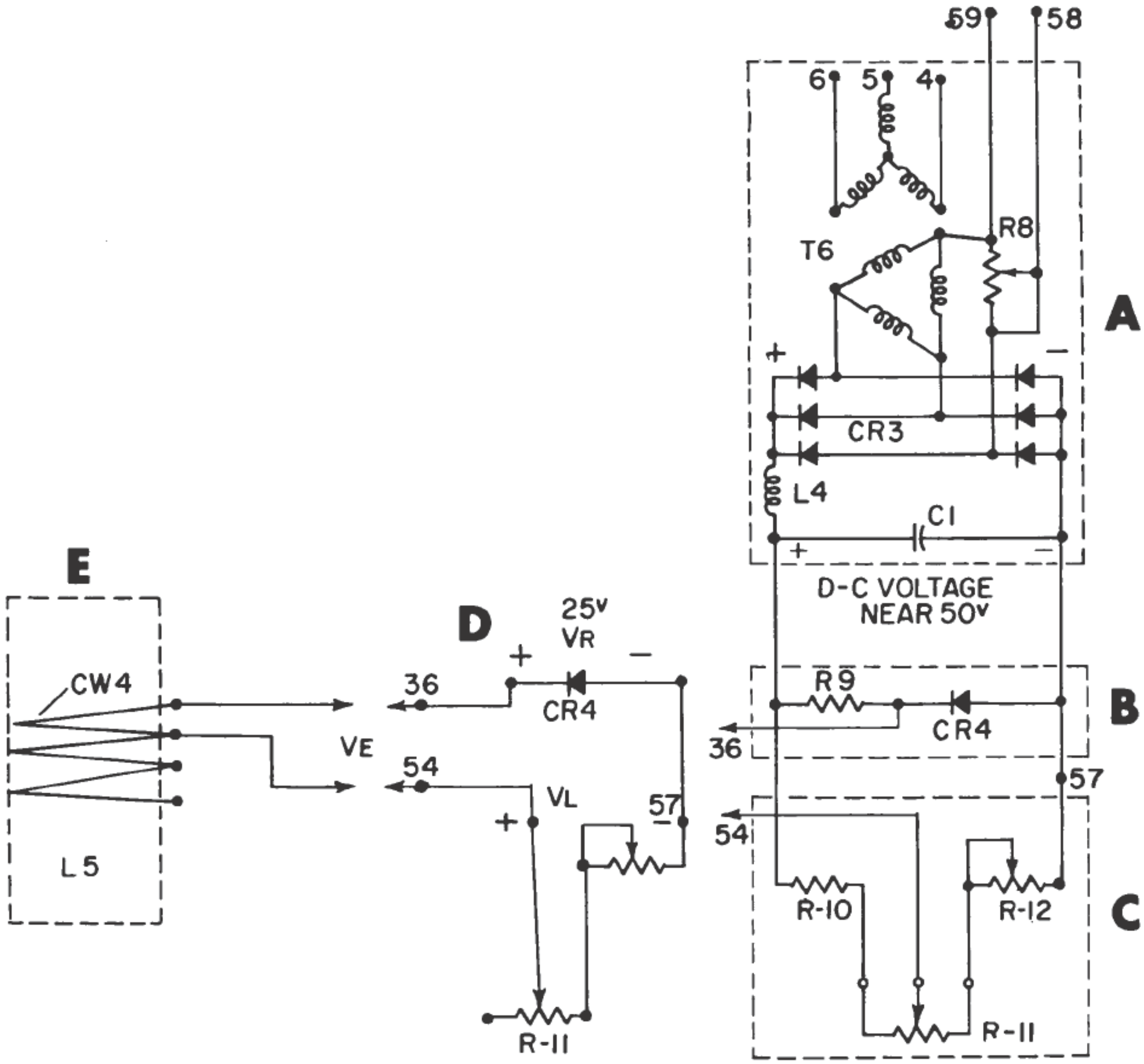

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Figure 4-18.—A. Sensing circuit.
B. Reference circuit.
B and C. Comparison circuit.
D. Error voltage circuit.
E. Control winding circuit of 1st stage magnetic amplifier.

Drooping resistor R9 limits the current through CR4 to a safe value. If the voltage (near 50 volts) across R9 and CR4 increases, the current increases in both items, but the voltage only increases across R9, leaving the voltage across CR4 at its original voltage value (25 volts). This is due to CR4 being an assembly of four silicon units, each unit operating in the natural breakdown (or Zener) region and having nearly constant 6.2 volt drop across each unit.

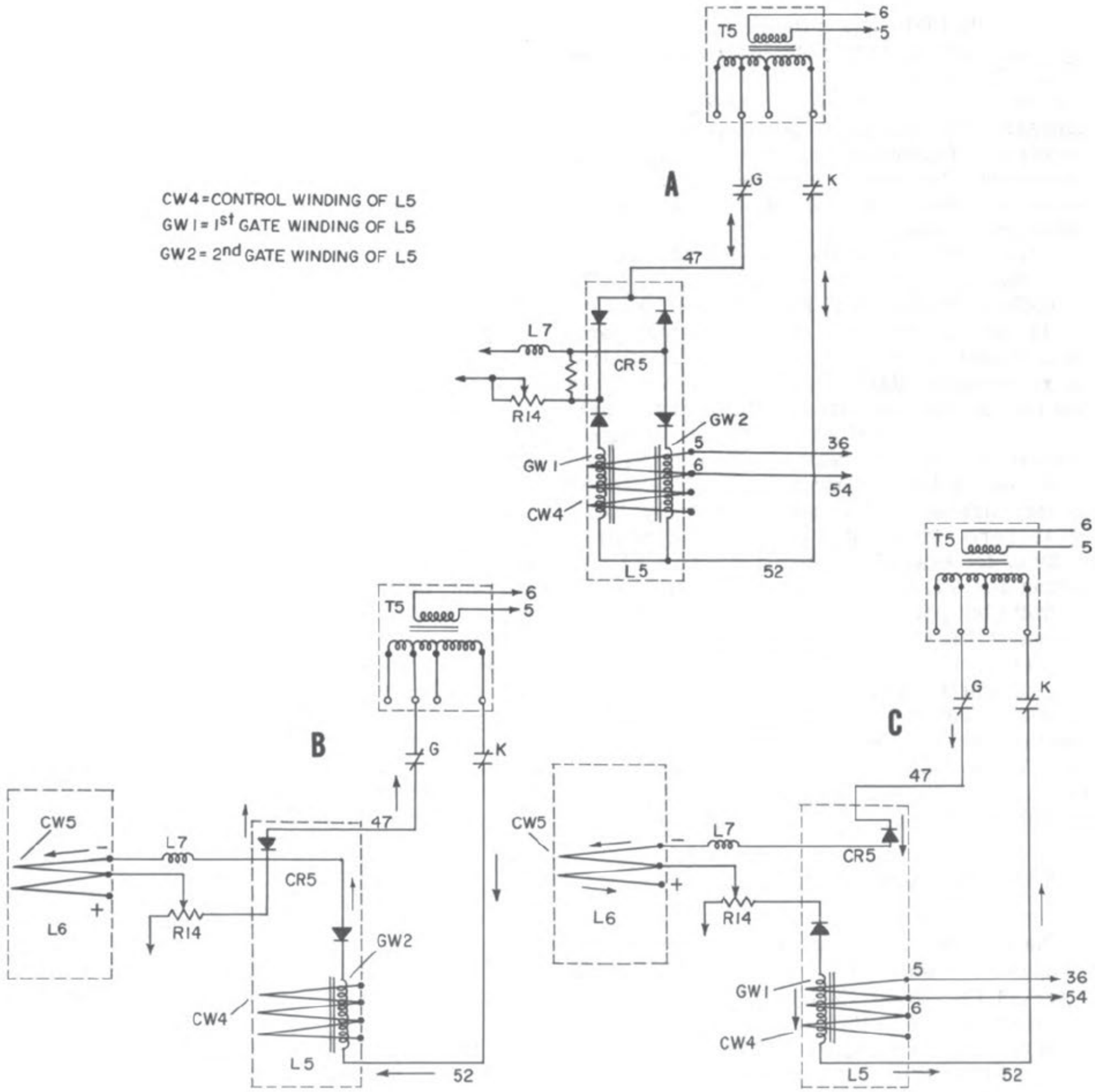

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Figure 4-19.—First stage magnetic amplifier.

Comparison Circuit

This comparison circuit (fig. 4-18C and B) consists of the reference circuit (fig. 4-18B) combined with resistors R10, R11, and R12 (fig. 4-18C). Its function is to compare the "average line-voltage" to the reference voltage and act on the 1st stage magnetic amplifier to correct any difference.

Error Voltage

Three sets of tests with a d-c voltmeter, which are made at the 3 terminals (numbered

36, 54, and 57) in figure 4-18, will reveal several facts that explain the ERROR VOLTAGE (V_E) produced across terminals No. 36 and No. 54 (fig. 4-18D).

Connect a d-c voltmeter to the V_E terminals. Disregard meter-polarity connections because, regardless of polarity selections, some of the performance tests will cause the meter to read downscale when the polarity (of the error voltage) reverses.

Initial changes in the amount of V_E are made by adjusting the slider on VOLTAGE ADJUSTING RHEOSTAT, R11. A slider position of R11 will be found where V_E registers zero. Then reposition the meter leads to verify that the reference voltage V_R (terminal No. 57 is negative; No. 36 is positive) will always remain at 25 volts, regardless of circuit changes. Relocate the meter leads to measure V_L and verify that it has the same value (25 volts) as V_R, for this special measurement only, when V_E is zero. If resistor R11 is readjusted to produce, for example, either a 27- or a 23-volt reading for VL then V_E has a numerical value of 2 volts but polarities are reversed. When V_L is greater than V_R, a direct current will flow in the control primary winding CW4 of the first-stage magnetic amplifier, and the automatic voltage regulator will reduce the exciter voltage, thereby lowering the line voltage. Conversely, when V_L is less than V_R, the regulator will increase the exciter voltage, thus raising the line voltage.

Magnetic Amplifier Circuits

The essential parts that comprise two stages, of magnetic amplifiers (figs. 4-19 and 4-17) consist of L5, CR5, R13, R14, L6, CR6 and R15.

Changes of generator voltage produce changes of current in the comparison circuit which are in the order of milliamperes while flowing in the control winding, CW4 (fig. 4-19). It is necessary to amplify considerably these initial small currents so their effect is in the order of several amperes in the final control windings, CW1, CW2, and CW3 of the SCPTs.

Two magnetic-amplifier gates (GW1 and GW2) function automatically and alternately in figure 4-19 to regulate the flow of a-c delivered by the 56-volt source of transformer, T5. The automatic regulation is achieved by saturating and desaturating the flux in the cores of GW1 and GW2. The degree of flux at any moment in each core is determined by the previously described conditions of d-c flow in the control winding, CW4.

The flow of gated a-c, and its conversion into d-c pulses in another control winding (CW5 of the power amplifier, L6), is readily traced by inspection of the arrows in figure 4-19B and 4-19C. These arrows alongside the conductors and rectifier elements are in the direction of electron flow during one half cycle (fig. 4-19B) and the other half cycle (fig. 4-19C).

A control winding would function to change its flux by means of either "d-c pulses" or "filtered d-c". Control winding CW4 employs filtered d-c by virtue of using capacitor, C1, in the reference circuit.

If, in figure 4-19B, the supply voltage (from transformer T5) is applied to the gate winding in series with its CW5 load, most of the voltage drop is across the gate winding (and very little voltage drop is across the CW5 control-winding load) provided the flux in the L5 core never reaches saturation. If the control-winding CW4 current is now changed so that the core flux reaches saturation for part of the cycle, the gate-winding inductance drops to a very low value for that part of the cycle and a portion of the supply voltage wave is applied to the load. The control winding current can be changed until the full supply voltage is applied to the load.

In this way, a control winding in each stage of the several saturated cores controls the output from the magnetic amplifier.

The series resistors R14, (fig. 4-19) and R15, (fig. 4-17) are adjusted so that each amplifier operates in the center of its saturation curve (for the magnetic core materials that are used).

Inductor L7 (fig. 4-19) is used to assure smooth continuous control of the second stage amplifier.

Transformer T5 is used to supply a-c power to the two magnetic amplifiers. It is also used to supply control current when operating in manual control.

Stabilizing Circuit

In any closed-loop regulating system containing several time constants and having high gain, sustained oscillations would be produced. These undesired oscillations are sometimes called HUNTING. To prevent hunting, a stabilizing filter circuit (resistors R17 and capacitor C3 in fig. 4-13) removes the normal ripple from

the exciter output voltage and another network (resistor R18 and capacitor C4) stabilizes the exciter output voltage.

The nonlinear resistor, R19, is used to suppress abnormally high transient voltages that may appear across the field rectifier, CR1.

Reactive Droop Compensation Circuit

Current transformer T4 and resistor R8 are used to obtain the generator drooping characteristic. The vector diagrams for this circuit are shown in figure 4-20A and B. Figure 4-20A shows the line voltages and currents for real and reactive loads. Figure 4-20B shows the voltages on the secondary of the transformer T6, along with the IR (voltage) drop (produced across resistor R8 due to its "current from the secondary, T4," called I4). For an in-phase, real load this "I4 R8" voltage drop shortens vector 01' but lengthens vector 02' and the average of the three vectors remains essentially constant. However, for reactive load the "I4 R8" voltage drop lengthtens vectors 01' and 02' and increases the average of the three vectors.

The regulator senses this higher voltage and thereby reduces the generator voltage, by giving the generator a drooping characteristic for reactive load.

Since the average of the three vectors 01', 02', and 03' did not change for real load, the generator should remain essentially constant.

The amount of reactive droop can be increased by increasing the resistance of resistor R8.

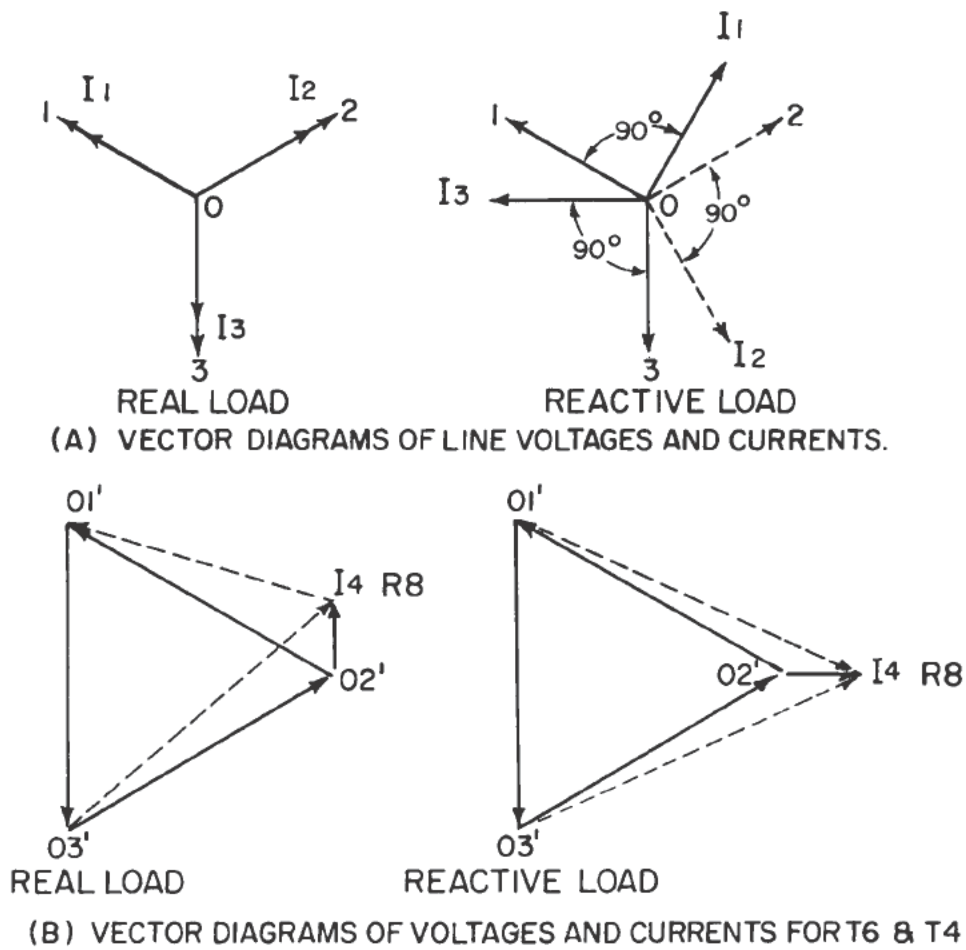

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Figure 4-20.—Vector diagrams of reactive droop circuit.

PARALLEL OPERATION

Before connecting an a-c generator in parallel with another machine for the first time, make a check of the reactive droop compensation circuit and check the prime mover instructions on parallel operation. Make the same test for both generators.

Deenergize the generator by stopping it or by turning switch S1 to the EMERGENCY or "OFF" position. Check the resistance of R8 and be certain its resistance is 2 ohms or more. Start the generator again, flash the field, and adjust the voltage adjusting rheostat for rated voltage with switch S1 in the "AUTO" position.

To check the polarity of the reactive droop circuit, note the terminal voltage of the generator at no load on automatic control. Then, add a lagging reactive load to the generator and again note the generator voltage. It SHOULD DECREASE. If the voltage rises, shut down the system and reverse the leads to the secondary of the current transformer.

Set resistor R8 so that the voltage decrease is the same for both generators and is not more than 4 percent of the nominal voltage when reactive load is applied. Set the same terminal voltage on the two generators, and check to see that the phase rotation is the same for both generators. Parallel the generators after they have been properly synchronized.

MANUAL OPERATION

To start the equipment, set the manual control rheostat R7 for minimum volts (fully counterclockwise). Set the control switch, S1, on MANUAL. Next hold the FLASHING switch S2 in the FLASH position until the generator starts to build up. Then adjust the manual control rheostat R7 to obtain the proper generator voltage. The system is now operating in MANUAL.

AUTOMATIC OPERATION

To operate the system in AUTOMATIC, turn the control switch S1 to the AUTO position and adjust the voltage regulating rheostat R11 to obtain the proper voltage.

The control switch S1 should never be left in an intermediate position between MANUAL and AUTOMATIC.

The control switch S1 has an emergency shutdown feature when placed in its OFF position. This can be used to quickly deenergize the generator in case of an emergency.

MAINTENANCE

The static regulator has no moving parts and its components are extremely rugged, therefore, little maintenance besides preventive maintenance is required.

Regular preventive steps must be assured by checking equipment for cleanliness and all connections for tightness.

Protecting all parts from moisture is essential, especially where selenium rectifiers are concerned. Although treated to stop destruction by moisture, continued exposure to moisture or mercury compounds tends to destroy selenium cells.

When replacing new rectifier units in CR4, 5, or 6 it is important not to overheat their leads when soldering. To prevent this, use a low temperature solder (resin core) and attach a small "heat sink" such as an alligator clip or grip with long nose pliers between the rectifier and the attached lead where the soldering is done. This will prevent damaging heat reaching the rectifier cell.

If it is necessary to apply a hipot (high-potential) test with megger or other devices to exciter or generator, all rectifiers must be shorted out with clip leads. High-potential tests are discussed in Chapter 60, BuShips Technical Manual.

CHAPTER 5

AUTOMATIC DEGAUSSING

Degaussing principles and manual degaussing systems are discussed in Electrician's Mate 3 & 2, NavPers 10546 (revised).

Automatic degaussing equipment is now installed in all new construction ships which rerequired the coil currents to be changed when the ship's heading changes. Most automatic degaussing equipment aboard Navy ships provides automatic compensation for the induced magnetization due to changes in the ship's heading only. Mine warfare ships, however, require installations which also provides automatic compensation for the induced magnetization caused by the ship's roll and pitch.

This chapter discusses automatic degaussing equipment using the GM-1A system as a representative system. The chapter also includes a brief discussion of degaussing installations for mine warfare ships.

GM-1A AUTOMATIC DEGAUSSING SYSTEM

The GM-1A system consists of equipment with kilowatt (KW) ratings for three classes of ships, as shown in table 5-1.

Table 5-1.—Maximum Rated Outputs for Representative Installations.

(Used on class DLG 6 through 15, CC(N)9 and LPD vessels.)

FP-QP coil	250 volts	±20 amperes	5 kw
M coil	250 volts	±100 amperes	25 kw
A coil	250 volts	±60 amperes	15 kw
FI-QI coil	250 volts	±36 amperes	9 kw

(Used on class DDG vessels.)

FP-QP coil	100 volts	±30 amperes	3 kw
M coil	250 volts	±100 amperes	25 kw
A coil	250 volts	±36 amperes	9 kw
FI-QI coil	250 volts	±36 amperes	9 kw

(Used on class DLG 16 through 24 and DLG(N) 25.)

FP-QP coil	250 volts	±20 amperes	5 kw
M coil	250 volts	±100 amperes	25 kw
A coil	250 volts	±36 amperes	9 kw
FI-QI coil	250 volts	±36 amperes	9 kw

The system consists of nine units: a degaussing switchboard, an automatic control unit (installed in the switchboard), a degaussing remote panel, two rectifier power supplies (M coil and FP-QP coil power supplies), two motor-generator sets (FI-QI coil and A coil), and two magnetic controllers which are used only with the A coil and FI-QI respectively. As illustrated in figure 5-1, the FP-QP coil power supply may be either of two different sizes having different output ratings. The A coil generator may likewise be either of two different sizes having different output ratings.

The system provides automatic degaussing currents for the FI-QI coil and the A coil, and manually metered (nonautomatic) currents for the M coil and the FP-QP coil. In case of failure of the automatic equipment, this part of the system also can be controlled manually.

DEGAUSSING SWITCHBOARD

Figure 5-2 illustrates the combination of two degaussing units; the switchboard and the automatic control unit.

The switchboard includes hinged front panel sections on which the operation controls and output current ammeters for the FP-QP coil and the M coil circuits are located. It also includes fixed panels on which are mounted the FI-QI coil and A coil output current ammeters, FI-QI and A motor-generator start buttons and

TABLE 5-2. —SWITCHBOARD CONTROLS.

Control or Indicator	Function
POWER TRANSFER SWITCH (S1101) (Not furnished with type FTR 3547CS and 3547DS equipments)	In the NORMAL ON position or the ALTERNATE ON position, S1101 supplies normal or alternate 440-volt, three-phase, 60-cycle ship's service power to the M and FP-QP coil circuits, and to the motor-generator sets for the FI-QI and A coils. In the OFF position, no 440-volt power is supplied to the degaussing circuits.
SHIP'S SERVICE POWER AVAILABLE NORMAL (I1103) and ALTERNATE (I1102) indicator lamps	Lamps indicate whether the normal or alternate 440-volt, three-phase, 60-cycle ship's service power is available.
M COIL POWER CIRCUIT BREAKER (S1202)	Supplies 440-volt, three-phase, 60-cycle power to the M coil circuits and provides overload protection.
FP-QP COIL POWER CIRCUIT BREAKER (S1302)	Supplies 440-volt, three-phase, 60-cycle power to the FP-QP coil circuits and provides an overload protection.
FI-QI COIL MOTOR CIRCUIT BREAKER (S1402)	Supplies 440-volt, three-phase, 60-cycle power to FI-QI motor-generator and provides short-circuit protection.
A COIL MOTOR CIRCUIT BREAKER (S1502)	Supplies 440-volt, three-phase, 60-cycle power to A coil motor-generator and provides short-circuit protection.
FI-QI COIL MOTOR RUNNING lamp, STOP and START (GENERATOR FIELD OVERLOAD RESET) buttons (S1429)	Energizes and stops FI-QI motor-generator set. Resets contacts of generator field overload relay K1433. POWER TRANSFER switch has to be in NORMAL ON or ALTERNATE ON position for motor-generator set to start.
A COIL MOTOR RUNNING lamp, STOP and START (GENERATOR FIELD OVERLOAD RESET) buttons (S1529)	Energizes and stops A coil motor-generator set. Resets contacts of generator field overload relay K1533. POWER TRANSFER SWITCH must be in NORMAL ON or ALTERNATE ON position for motor-generator set to start.
M COIL POLARITY REVERSING SWITCH (S1203)	Sets the polarity of the M degaussing coil with special positions for minimum output operation.
FP-QP COIL POLARITY REVERSING SWITCH (S1303)	Sets the polarity of the FP-QP degaussing coil with special positions for minimum output operation.
M COIL CURRENT ADJUSTMENT (T1206)	Adjusts the magnitude of the M degaussing coil current.
FP-QP COIL CURRENT ADJUSTMENT (T1306)	Adjusts the magnitude of the FP-QP degaussing coil current.

TABLE 5-2. —SWITCHBOARD CONTROLS—(Cont.)

Control or Indicator	Function
FI-QI COIL ammeter (M1401)	Indicates FI-QI degaussing coil current.
A COIL ammeter (M1501)	Indicates A degaussing coil current.
FP-QP COIL ammeter (M1301)	Indicates FP-QP degaussing coil current.
M COIL ammeter (M1201)	Indicates M degaussing coil current.
M COIL TROUBLE indicator lamps (I1209 and I1210)	Light if the M coil degaussing current varies more than 5 percent from a particular setting.
FP-QP COIL TROUBLE indicator lamps (I1309 and I1310)	Light if the FP-QP coil degaussing current varies more than 5 percent from a particular setting.
POWER SUPPLY TEMPERATURE ALARM (I1111)	The alarm bell sounds when the M or the FP-QP coil power supply is overheating. It also sounds when the POWER TRANSFER SWITCH is ON and the M COIL POWER CIRCUIT BREAKER is OPEN.
ALARM BELL CUT-OFF switch (S1104)	In ON position, the switch places the alarm bell in the warning circuit. In OFF position, the bell is removed from the warning circuit. The overheating lamps remain in the circuit when the bell is turned off.
FP-QP COIL POWER SUPPLY OVERHEATING indicator lamps (I1307 and I1308)	Light when the FP-QP coil power supply is overheating.
M COIL POWER SUPPLY OVERHEATING indicator lamps (I1207, I1208)	Light when the M coil power supply is overheating. Lamps also light if the POWER TRANSFER SWITCH is ON and the M COIL POWER CIRCUIT BREAKER is OPEN.
M COIL FILTER CAPACITOR FUSE BLOWN indicator lamps (I1219 and I1220)	Light if the filter capacitor fuses in the M coil power supply have blown.
FP-QP COIL FILTER CAPACITOR FUSE BLOWN indicator lamps (I1319 and I1320)	Light if the filter capacitor fuses in the FP-QP coil power supply have blown.

reset buttons. The switchboard controls and their functions are listed in table 5-2.

The automatic control unit is shown installed in the switchboard in figures 5-2 and 5-3. The control unit includes a hinged front panel which contains the operating controls for the A and FI-QI coils. The functions of these controls are given in table 5-3.

REMOTE CONTROL PANEL

The remote control panel may be either of two types that use identical parts, which are arranged differently to perform identical functions, while mounted vertically (fig. 5-4), or mounted horizontally (fig. 5-5).

The remote panel is used for monitoring the A, FI-QI, FP-QP and M coil currents. Also, if the MANUAL LOCAL-REMOTE switch (S4135 fig. 5-3) is set to the REMOTE setting, then the remote panel is used for emergency manual operation of the A and/or FI-QI coils by means of the MANUAL CONTROL FI-QI AND A COILS' switch (S5111 figs. 5-4 and 5-5). The functions of the operating controls and indicators of the remote panel are described in table 5-4.

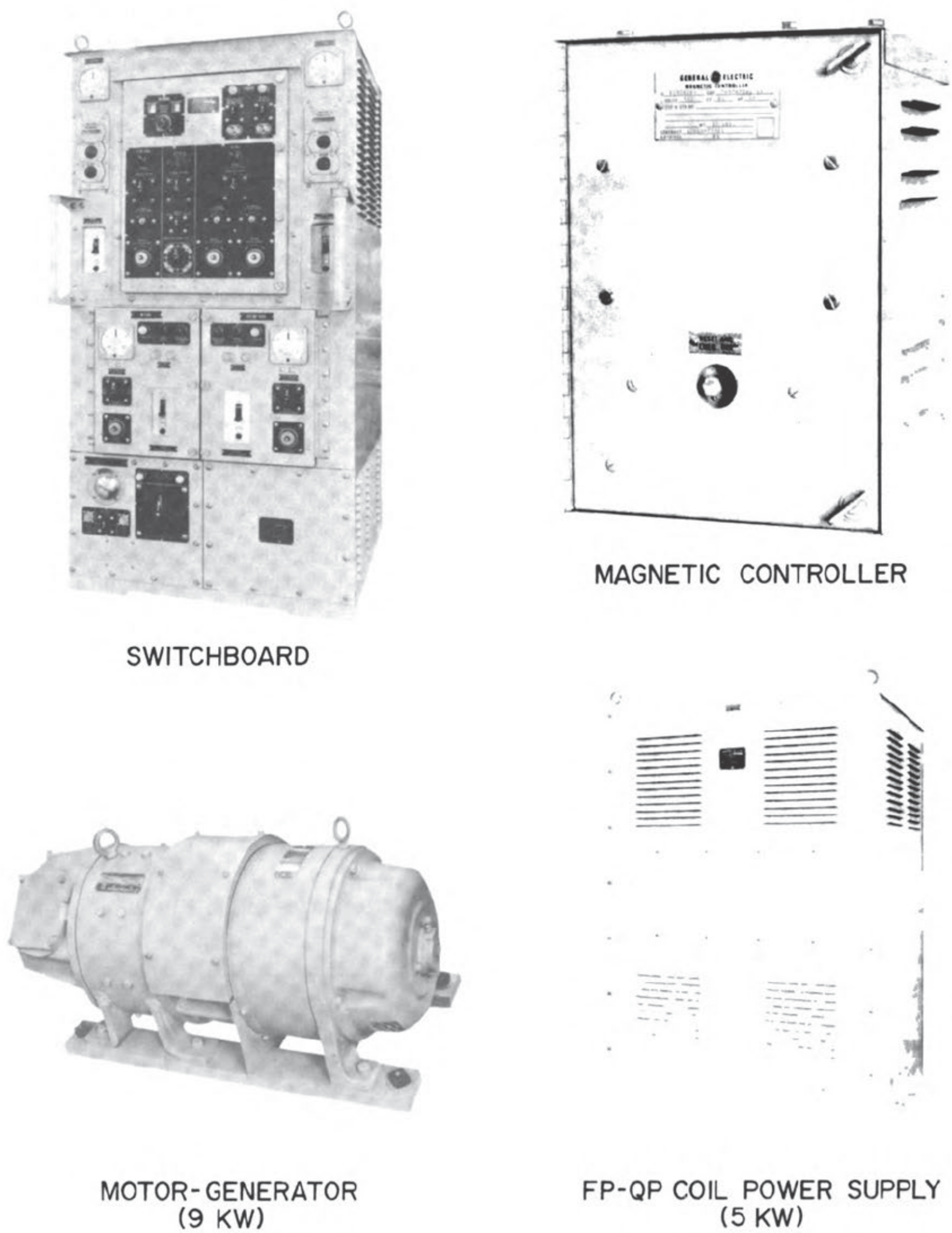

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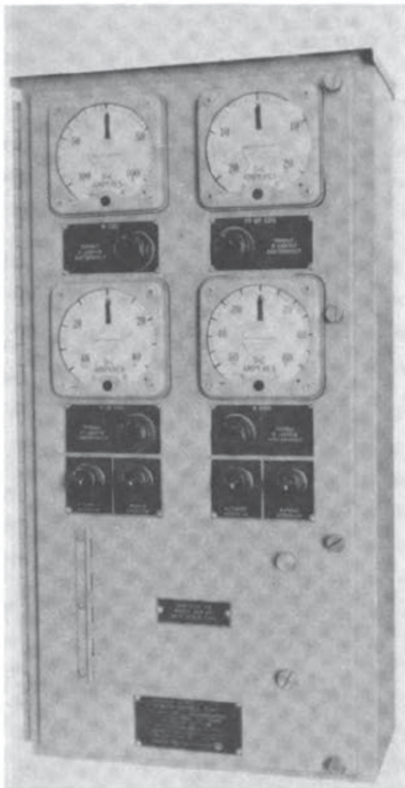
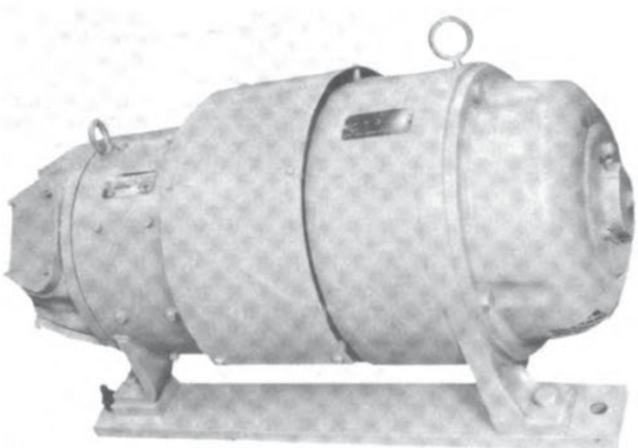
Figure 5-1.—Automatic control and power supply equipment.

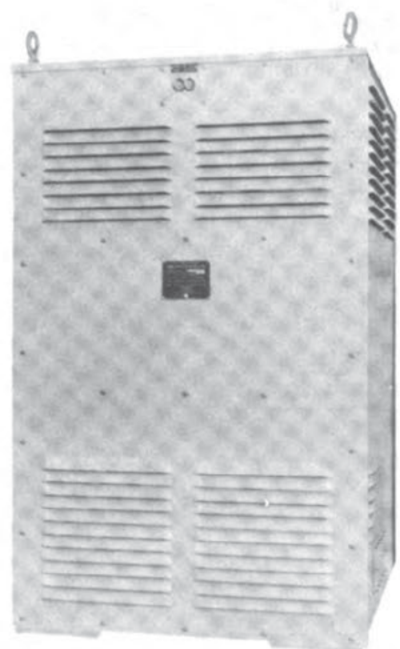


REMOTE CONTROL PANEL

M COIL POWER SUPPLY
(25 KW)



MOTOR GENERATOR
(15 KW)



FP-QP COIL POWER SUPPLY
(3 KW)

Figure 5-1.—Continued

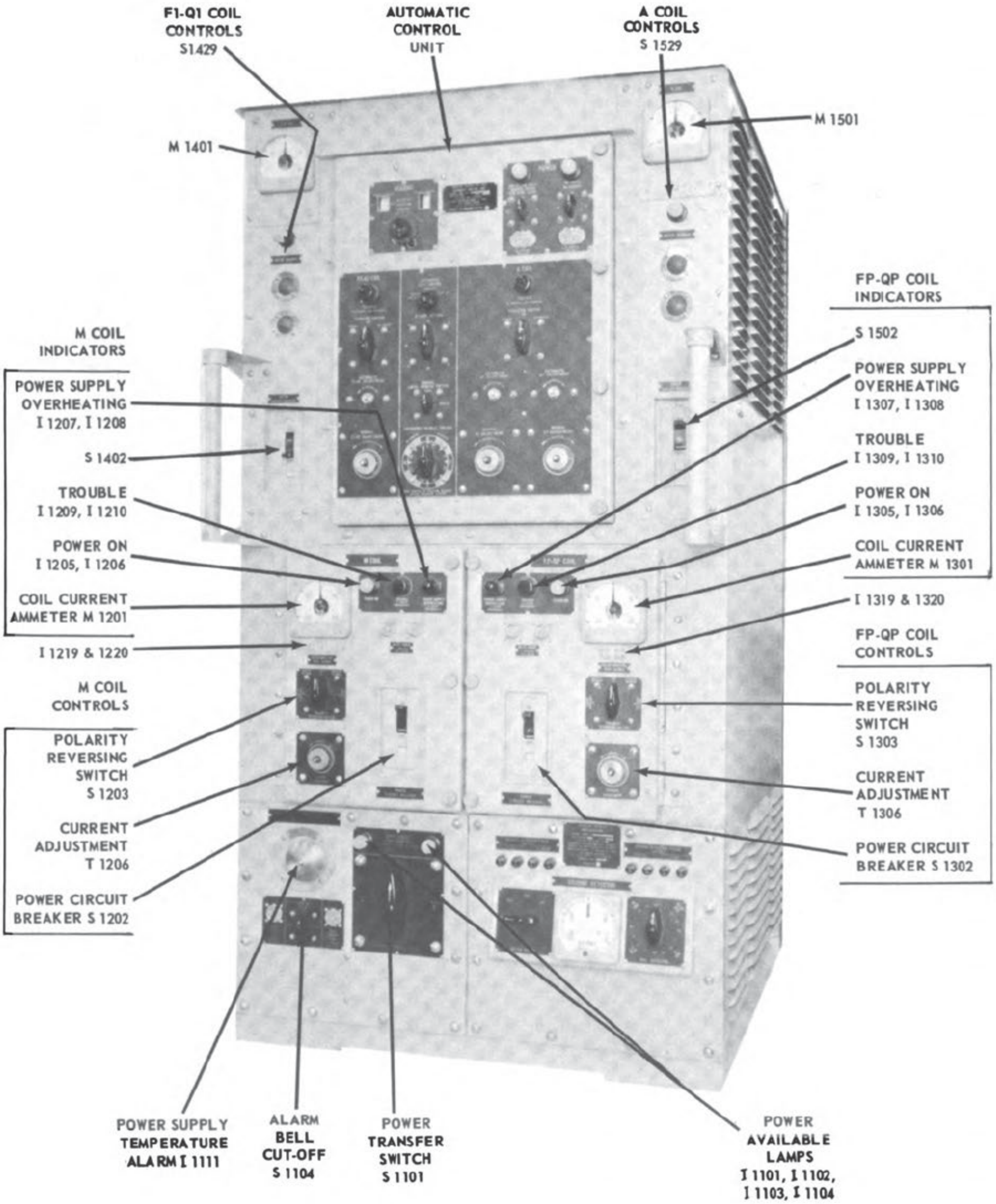


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Figure 5-2.—Switchboard, including automatic control unit, front view.

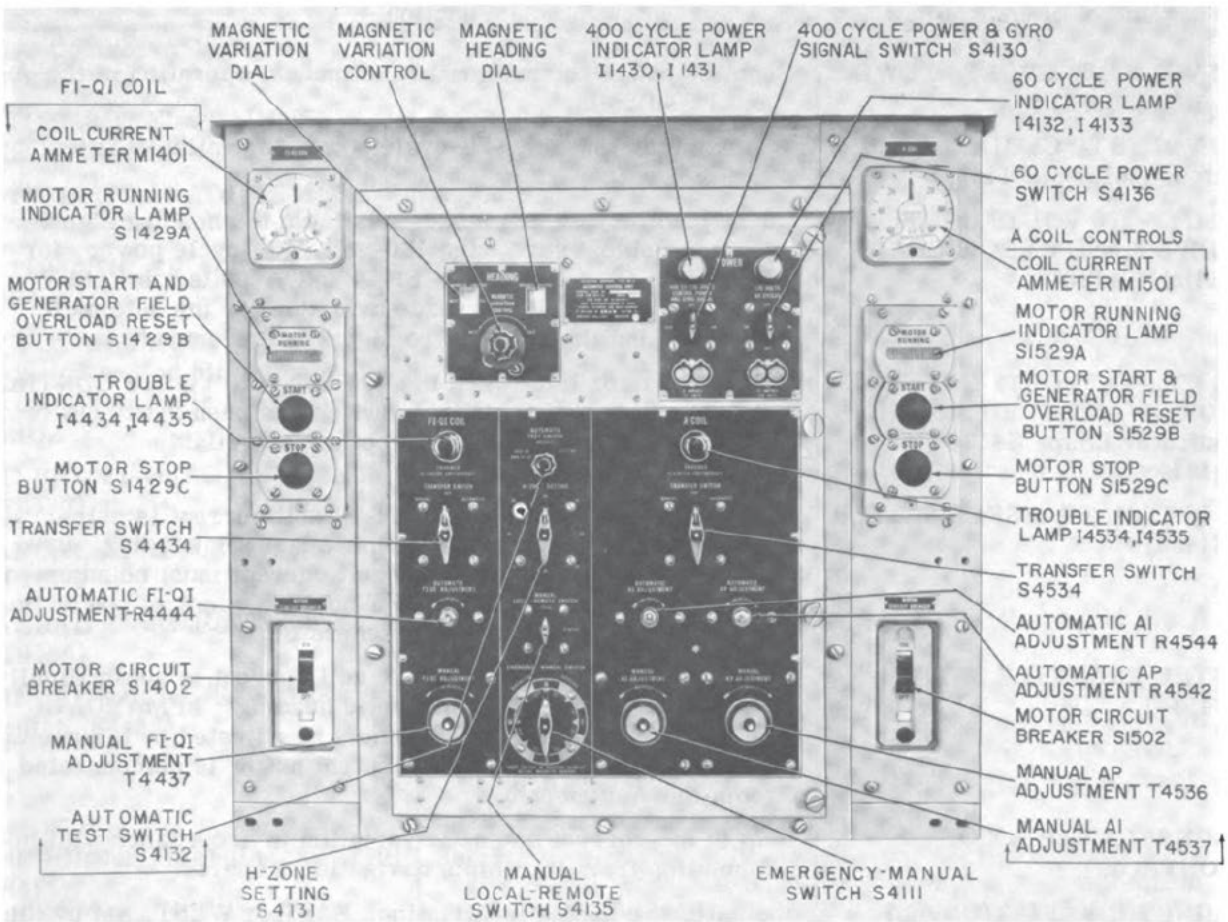

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Figure 5-3.—Switchboard, upper section, including automatic control unit, front view.

POWER SUPPLIES

Three sources of input power are normally used to energize the electrical units of the Type GM-1A automatic degaussing equipment:

1. The high power circuits of the equipment are energized from the ship's 3-phase, 60-cycle, 440-volt service line. The POWER TRANSFER SWITCH (S1101) on the switchboard permits the choice of NORMAL OR ALTERNATE supplies of this source.
2. The low power circuits of the automatic control circuits and the heading signal assembly are energized from a single-phase, 400-cycle, 120-volt line.
3. The low-power circuits of the power amplifiers and the heading signal assembly are energized from a single-phase, 60-cycle, 120-volt line. In three-course emergency operation only the single-phase, 60-cycle, 120-volt source is used.

Rectifier Power Supplies

To convert the ship's a-c power into d-c power that is required by the M coil and FP-QP coil, selenium and silicon rectifiers are used for the type GM-1A degaussing system. The need for a center-tapped power transformer is eliminated by connecting four half-wave rectifiers to form the familiar single-phase full-wave bridge rectifier circuit shown in figure 5-6A. One of its three applications in

TABLE 5-3. —AUTOMATIC CONTROL UNIT CONTROLS.

Control or Indicator	Function
120 VOLTS 60 CYCLES POWER switch (S4136)	Supplies power for automatic and manual operation of the A and FI-QI coils.
120 VOLTS 60 CYCLES POWER lamps (I4132 and I4133)	Indicate that 120-volt, 60-cycle power is available.
400 CY. -120 VOLTS CONTROL POWER AND GYRO SIGNAL switch (S4130)	In ON position, switch makes available the heading signal from the ship's gyro, and 120-volt, 400-cycle power, for automatic operation of the FI-QI and A coils. In TEST position, power is still made available for the automatic circuits, but the ship's gyro signal is disconnected.
400 CY. -120 VOLTS CONTROL POWER AND GYRO SIGNAL indicator lamps (I4130 and I4131)	Indicator lamps light when the 400 CY. -120 VOLTS CONTROL POWER AND GYRO SIGNAL switch has been set to ON or TEST position and 400-cycle power is available.
FI-QI COIL TRANSFER SWITCH (S4434)	In AUTOMATIC position, the FI-QI coil current is automatically controlled by the ship's magnetic heading. In MANUAL position, the FI-QI coil current must be adjusted by the manual control. In OFF position, control power is disconnected from the FI-QI generator.
A COIL TRANSFER SWITCH (S4534)	In AUTOMATIC position, the A coil current is automatically controlled by the ship's magnetic heading. In MANUAL position, the A coil current must be adjusted by the manual controls. In OFF position, control power is disconnected from the A generator.
MAGNETIC VARIATION CONTROL	Sets in the correct magnetic variation in accordance with information from the ship's navigational charts.
MAGNETIC VARIATION dial	Indicates the magnetic variation, EAST or WEST, set by the MAGNETIC VARIATION CONTROL.
MAGNETIC HEADING dial	Indicates the ship's magnetic heading.
AUTOMATIC TEST SWITCH (S4132)	In OPERATE position, the FI-QI coil current and the induced component of the A coil current are controlled by magnetic heading signals, and the permanent component of the A coil current is adjusted by the automatic AP adjustment and manual AP adjustment controls. In the TEST AI AND FI-QI position to the magnetic heading signals, the FI-QI and AI circuits are both replaced by calibration signals which are equal to the maximum magnetic heading signals, and the permanent component of the A coil current is reduced to zero. In TEST AP position, the magnetic heading signals are reduced to zero, leaving only the permanent component of the A coil current.
H ZONE SETTING switch (S4131)	Adjusts the FI-QI and A coil signals to compensate for the horizontal component of the earth's magnetic field. Eight fixed steps are provided for latitude zones of 0. 05 gauss to 0. 40 gauss.

TABLE 5-3. —AUTOMATIC CONTROL UNIT CONTROLS—(Cont.)

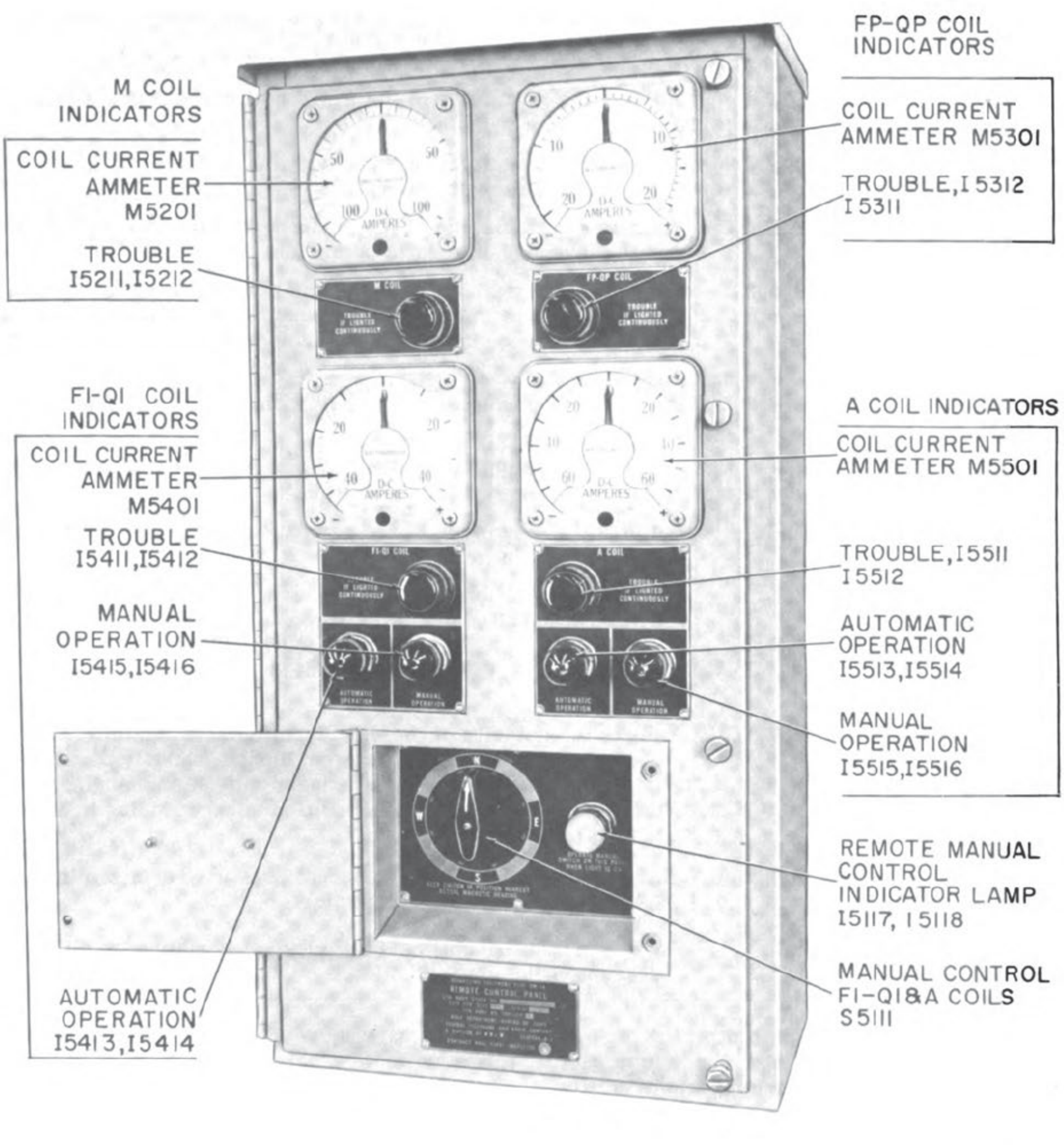
Control or Indicator	Function
AUTOMATIC FI-QI ADJUSTMENT (R4444)	Adjusts the magnitude of the FI-QI coil current in automatic operation.
AUTOMATIC AI ADJUSTMENT (R4544)	Adjusts the magnitude of the induced portion of the A coil current in automatic operation.
AUTOMATIC AP ADJUSTMENT (R4542)	Adjusts the magnitude of the permanent component of the A coil current in automatic operation.
AP POLARITY SWITCH S4533 (located behind hinged panel door of automatic control unit).	Determines the polarity sign of the permanent portion of the A coil current in automatic or manual operation. Also has an OFF position which gives zero permanent A coil current.
MANUAL FI-QI ADJUSTMENT (T4437)	Adjusts the magnitude of the FI-QI coil current in manual operation.
MANUAL AI ADJUSTMENT (T4537)	Adjusts the magnitude of the induced component of the A coil current in manual operation.
MANUAL AP ADJUSTMENT (T4536)	Adjusts the magnitude of the permanent component of the A coil current in manual operation.
MANUAL LOCAL-REMOTE switch (S4135)	In LOCAL position, the switchboard EMERGENCY-MANUAL SWITCH S4111 controls the three-course manual current. In REMOTE position, the remote MANUAL CONTROL FI-QI AND A COILS switch S5111 controls the manual current.
EMERGENCY-MANUAL SWITCH (S4111)	Selects the polarity of the FI-QI coil current and the AI component of the A coil current during manual operation in accordance with the ship's magnetic heading angle. Switch should be set to the position corresponding to ship's magnetic heading.
FI-QI COIL TROUBLE indicator lamps (I4434 and I4435)	Light when the FI-QI coil current does not remain within five percent of the correct value.
A COIL TROUBLE indicator lamps (I4534 and I4535)	Light when the A coil current does not remain within five percent of the correct value.

figure 5-7 is shown at the output of the preamplifier that feeds into the booster amplifier.

The familiar three-phase, full-wave rectifier is shown in figure 5-6B and its application is noted at the output of the booster amplifier in figure 5-7. (See foldout for figure 5-7.)

The CURRENT-HANDLING ability of a bridge rectifier may be increased by connecting two or more (half-wave) rectifier units in parallel. Thus, figure 5-6C is transformed from figure 5-6B, in order to double the output current-handling ability. Likewise, figure 5-6D is capable of delivering (as much as) triple the amount that figure 5-6B can handle because three units are paralleled within each phase. The circuits of fig. 5-6D and E are used in the rectifiers for the 3KW and 5KW FP-QP power supplies shown in figure 5-1.

The VOLTAGE-HANDLING ability of a simple bridge rectifier may be doubled by stacking two units in SERIES within each leg of the bridge as in figure 5-6E. Since figure 5-6E also contains PARALLEL pairs of the series-connected stacks, each parallel group (in fig. 5-6E) functions to double the CURRENT-HANDLING ability. Because each phase thereby



111.41

Figure 5-4.—Remote panel, vertical type.

doubles the current (as well as doubling the voltage) the net POWER-HANDLING ability is quadrupled. This circuit, like all full-wave, three-phase rectifier circuits, produces a d-c output having a ripple frequency three times higher than can be obtained from a single-phase, full-wave circuit, thus yielding a higher average current value.

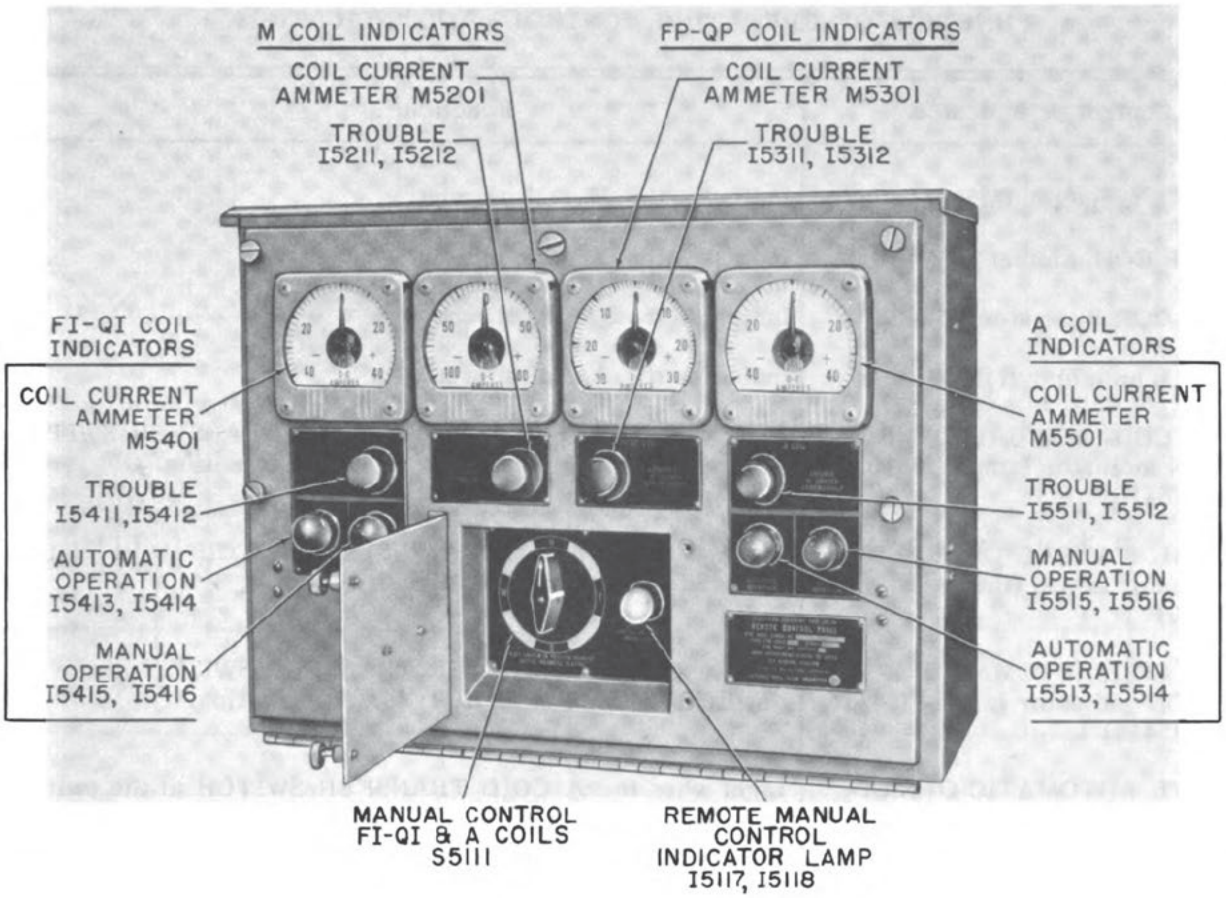


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Figure 5-5.—Remote panel, horizontal type.

Motor Generator Sets

The m-g sets are used with the A & FI-QI channels (fig. 5-1). The sets consist of the shunt-wound direct-current generator and the 3-phase, 440-volt induction drive motor. The drive motors are 23 and 14 hp for the 15 and 9 kw sets, respectively.

Only the degaussing generator is unusual in that it has two sets of field windings. The field windings for the A coil generator are supplied by the two outputs (positive output to one generator field and negative output to the other generator field) of the A-channel power amplifier (fig. 5-8).

The two outputs of fig. 5-8 supply field-magnetizing forces that oppose each other so that the generator output will be zero when the two power amplifier outputs are the same. An unbalance in the heading signal changes the power amplifier outputs, which results in a generator output that is proportional to the difference between the currents in the two sets of generator field windings. The field windings for the FI-QI generator are similarly supplied by the outputs from the FI-QI power amplifier.

Magnetic Controllers

Each motor generator set is supplied with magnetic controller equipment mounted within an enclosing case shown in figure 5-1. The materials enclosed within a controller case consist of a (size 2) contactor, an overload relay, 2 heater assemblies for the relay, an overload reset assembly, and 2 fuse holders with 2 fuses.

TABLE 5-4. —REMOTE PANEL

FUNCTION OF OPERATING CONTROLS AND INDICATORS.

Control or Indicator	Function
M COIL ammeter (M5201)	Indicates the M coil current.
FP-QP COIL ammeter (M5301)	Indicates the FP-QP coil current.
FI-QI COIL ammeter (M5401)	Indicates the FI-QI coil current.
A COIL ammeter (M5501)	Indicates the A coil current.
FI-QI COIL MANUAL OPERATION indicator lamps (I5415 and I5416)	Light when the FI-QI COIL MANUAL TRANSFER SWITCH at the switchboard is set to MANUAL position.
A COIL MANUAL OPERATION indicator lamps (I5515 and I5516)	Light when the A COIL TRANSFER SWITCH at the switchboard is set to MANUAL position.
FI-QI COIL AUTOMATIC OPERATION indicator lamps (I5413 and I5414)	Light when the FI-QI COIL TRANSFER SWITCH at the switchboard is set to AUTOMATIC position.
A COIL AUTOMATIC OPERATION indicator lamps (I5513 and I5514)	Light when the A COIL TRANSFER SWITCH at the switchboard is set to AUTOMATIC position.
M COIL TROUBLE indicator lamps (I5211 and I5212)	Light when the M coil degaussing current varies more than five percent from a particular setting.
FP-QP COIL TROUBLE indicator lamps (I5311 and I5312)	Light when the FP-QP coil degaussing current varies more than five percent from a particular setting.
FI-QI COIL TROUBLE indicator lamps (I5411 and I5412)	Light if the FI-QI coil current does not remain within five percent of the correct value.
A COIL TROUBLE indicator lamps (I5511 and I5512)	Light if the A coil current does not remain within five percent of the correct value.
OPERATE MANUAL SWITCH indicator lamps (I5517 and 15518). (Located in recess behind MANUAL CONTROLS door)	Light when the MANUAL LOCAL-REMOTE SWITCH on the switchboard is in the REMOTE position and at least one TRANSFER SWITCH is in MANUAL position. When the lamp is lit, the coil or coils transferred to manual operation is controlled by the MANUAL CONTROL S5111.
MANUAL CONTROL FI-QI AND A COILS (S5111) (Located in recess behind MANUAL CONTROLS door)	Selects the polarity of the FI-QI and A coil currents during manual operation in accordance with the ship's magnetic heading angle. Switch should be set to position corresponding to ship's magnetic heading.

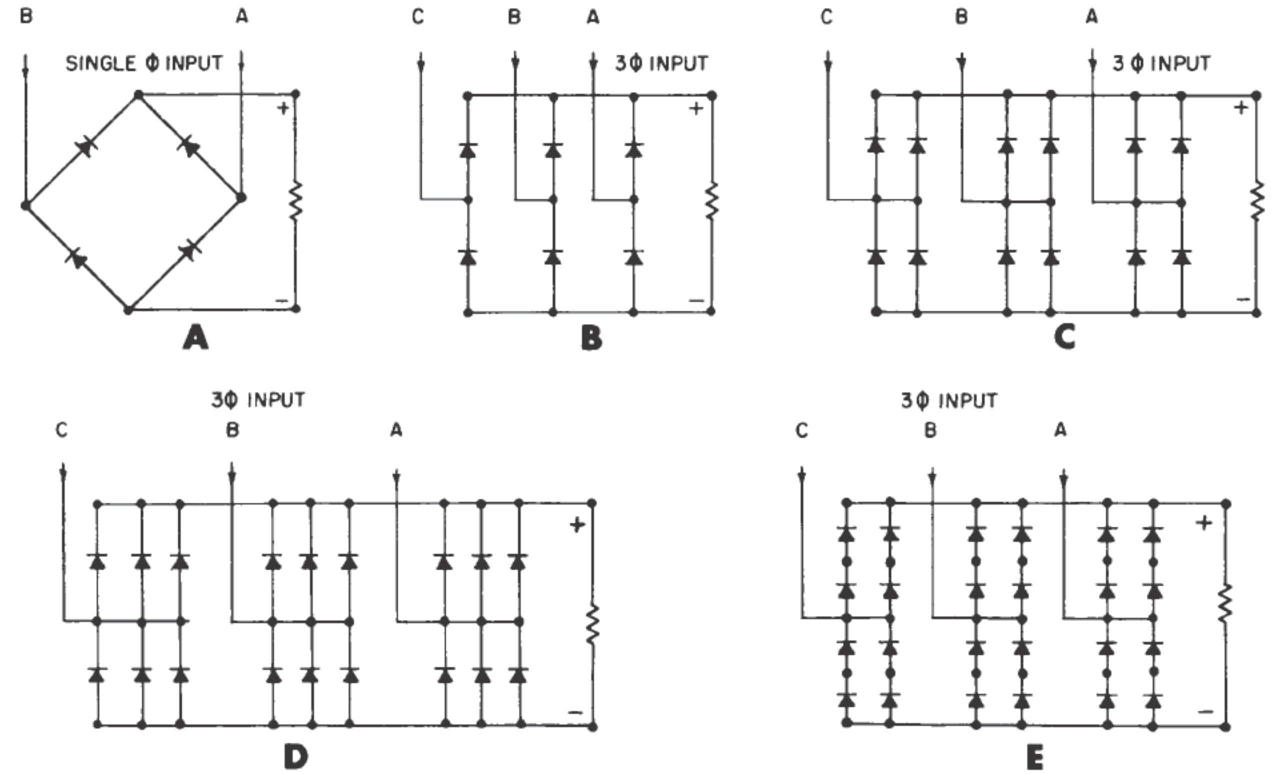

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Figure 5-6.—Rectifier circuit applications.

The size 2 contactor is installed for either a 23 hp or a 14 hp motor. The overload relay heater assemblies differ in their ratings depending upon the drive motor used.

FUNCTIONAL OPERATION

The functional operation of the degaussing system can be understood by reference to the block and schematic diagrams and table 5-5 which follow.

The physical location of each electrical part is indicated by the first digit of its circuit reference symbol and identified by the code given in table 5-5.

The circuit in which each electrical part is used is indicated by the second digit of its circuit symbol, and its meaning is identified in table 5-5.

Heading Assembly

The heading assembly receives the heading signal from the ship's gyro system and converts the signal into a magnetic heading signal by means of the manually operated MAGNETIC VARIATION CONTROL (fig. 5-9). The heading synchro B4131 (fig. 5-10, part 1) directly drives the rotor of the resolver B4130. The stator of resolver B4130 is energized from the H-ZONE SETTING switch. Each output of the resolver is proportional to the sine or cosine function of the MAGNETIC HEADING and to the voltage applied to the H-ZONE SETTING switch.

Table 5-5.—Circuit Reference Symbol Code.

First Digit	Second Digit
1 Switchboard	1 Common
2 M Coil power supply	2 M Coil
3 3 kw FP-QP power supply	3 FP-QP Coil
4 Automatic control unit	4 FI-QI Coil
5 Remote panel	5 A Coil
6 5 kw FP-QP power supply	

Because the heading input signal is in terms of true north, whereas the degaussing system requires a heading in terms of magnetic north, the above-described MAGNETIC VARIATION CONTROL is used for manually compensating an existing difference by unlocking the control (on the front panel of the automatic control unit) and rotating the entire housing of synchro receiver B4131, including its attached MAGNETIC VARIATION DIAL. The number of degrees of rotation is read on the MAGNETIC VARIATION DIAL. Since the rotor of B4131 is mechanically coupled with the resolver of B4130, the setting of the dial also corrects the setting of the resolver, and the control can be locked for automatic operation. (See foldout for figure 5-10.)

FI-QI and A Channels

Signals for the FI-QI and A channels are obtained from the Sola constant voltage transformer, T4130. The output voltage of this transformer (fig. 5-10, part 1) remains constant even if the input voltage and frequency vary within specified limits. This property of the Sola transformer is obtained by using a carefully designed magnetic core that saturates when the nominal input voltage is exceeded.

The A and FI-QI channels are similar except that (a) the A and FI-QI channels operate from sine and cosine outputs of the heading assembly, respectively, and (b) only the A channel has provisions for furnishing a perm bias component of the degaussing current to compensate for the ship's permanent magnetism. Circuit symbols mentioned in the following paragraphs are those of the automatic control stages of the A channel or of components common to both A and FI-QI channels.

H-ZONE SETTING SWITCH.—Since the magnitude of the horizontal magnetization induced in the ship is dependent on the geographical zone in which the ship is traveling, the degaussing current must be initially adjusted for changes in the earth's horizontal magnetization in different latitude zones. This adjustment is made by the H-ZONE SETTING switch, S4131. This switch changes taps on the H-zone auto-transformer. There are eight equally spaced taps which are calibrated for H-zone settings of 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, and 0.40 gauss. The horizontal component of the earth's field reaches a maximum of 0.40 gauss at the equator and decreases to zero at the magnetic poles. The H-ZONE SETTING switch accordingly sets the maximum amplitude of the degaussing coil currents as required for the latitude zone in which the ship is traveling.

DEMODULATORS.—Two d-c outputs are obtained from each demodulator. These outputs are supplied to separate control windings in the preamplifier reactors L4530 and L4430 (fig. 5-10, part 2).

One of the demodulator outputs is equal to the sum of the reference voltage and the signal; the other is equal to the difference between the reference voltage and the signal.

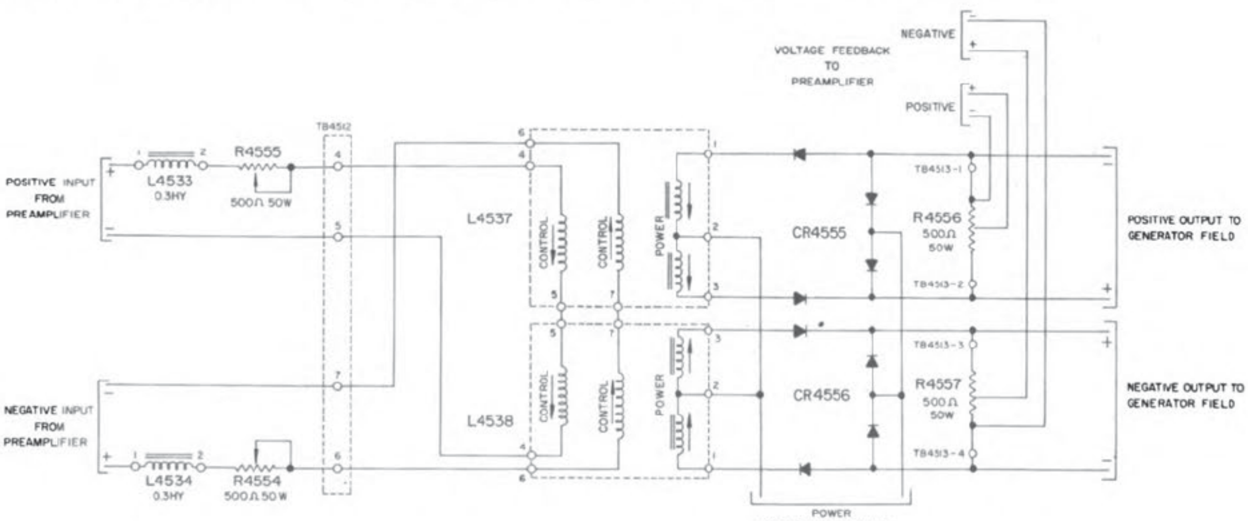

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Figure 5-8.—A channel power amplifier, simplified schematic diagram.

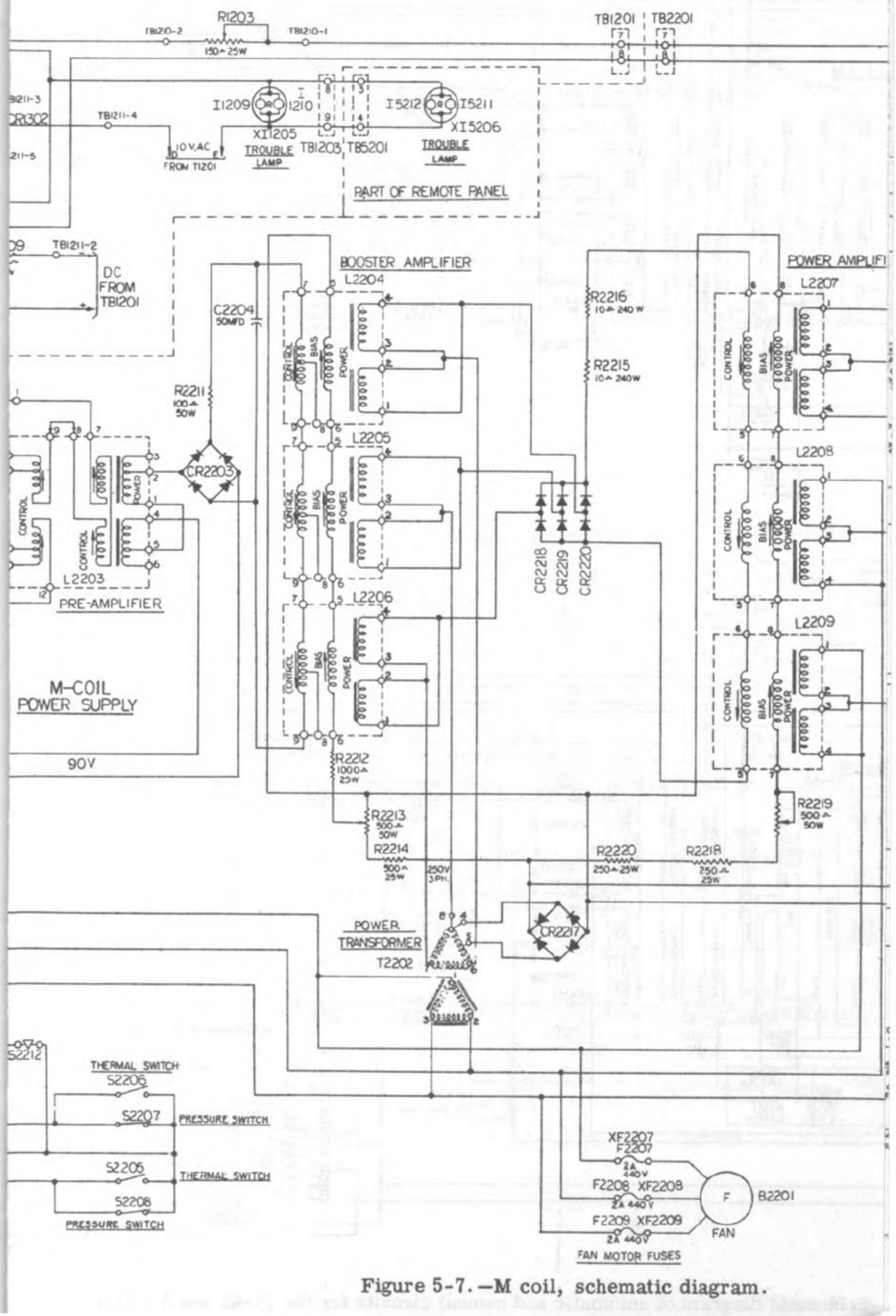
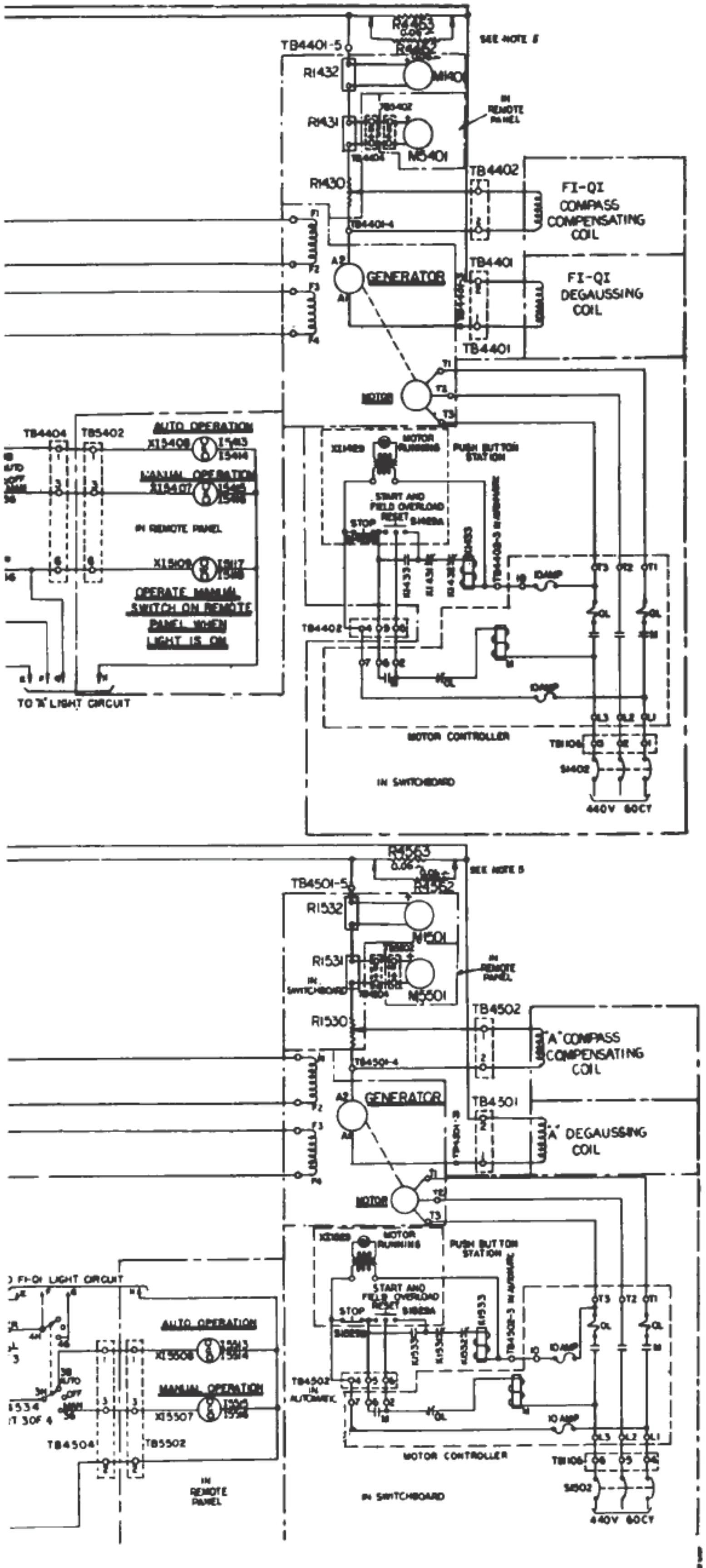


Figure 5-7. —M coil, schematic diagram.



SEE NOTE 5
TB4401-5
R1432
R1431
IN REMOTE PANEL
R1430
TB4402
FI-QI COMPASS COMPENSATING COIL
TB4401-4
GENERATOR
TB4401
FI-QI DEGAUSSING COIL
MOTOR
TB4404
TB5402
AUTO OPERATION
MANUAL OPERATION
IN REMOTE PANEL
OPERATE MANUAL SWITCH ON REMOTE PANEL WHEN LIGHT IS ON
TO "A" LIGHT CIRCUIT
MOTOR RUNNING
PUSH BUTTON STATION
START AND FIELD OVERLOAD RESET
STOP
10AMP
MOTOR CONTROLLER
IN SWITCHBOARD
440V 60CY
SEE NOTE 5
TB4501-5
R1532
R1531
IN SWITCHBOARD
IN REMOTE PANEL
R1530
TB4502
"A" COMPASS COMPENSATING COIL
TB4501-4
GENERATOR
TB4501
"A" DEGAUSSING COIL
MOTOR
MOTOR RUNNING
PUSH BUTTON STATION
FI-QI LIGHT CIRCUIT
START AND FIELD OVERLOAD RESET
STOP
AUTO OPERATION
MANUAL OPERATION
TB4502 IN AUTOMATIC
10 AMP
MOTOR CONTROLLER
TB4504
TB5502
IN REMOTE PANEL
IN SWITCHBOARD
440V 60CY

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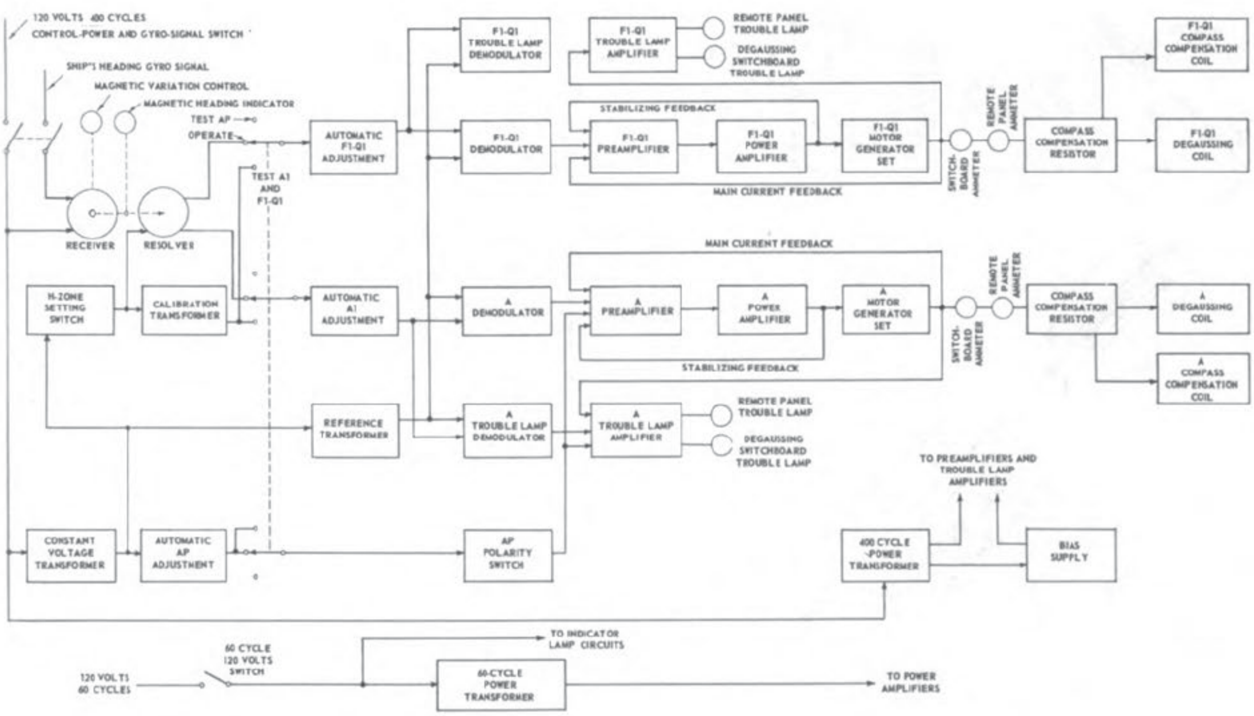

111.46

Figure 5-9.—Automatic FI-QI and A channels, block diagram.

Figure 5-11 shows a simplified schematic of ıe demodulator for the A channel. With no sig-al output from the resolver sine winding the ridge is balanced and no current flows through ıe center arm. For the first half cycle, (elec-ron) current flow may be traced from terminal of T4133, to terminal 2, through CR4534 down through control winding 1, through CR4532, through CR4538, up through control winding 2, through CR4536, and back to terminal 3 via terminal 4. The d-c currents flowing in control windings 1 and 2 are equal in magnitude and of opposite polarity. Tracing the flow for the second half cycle will show that the control winding

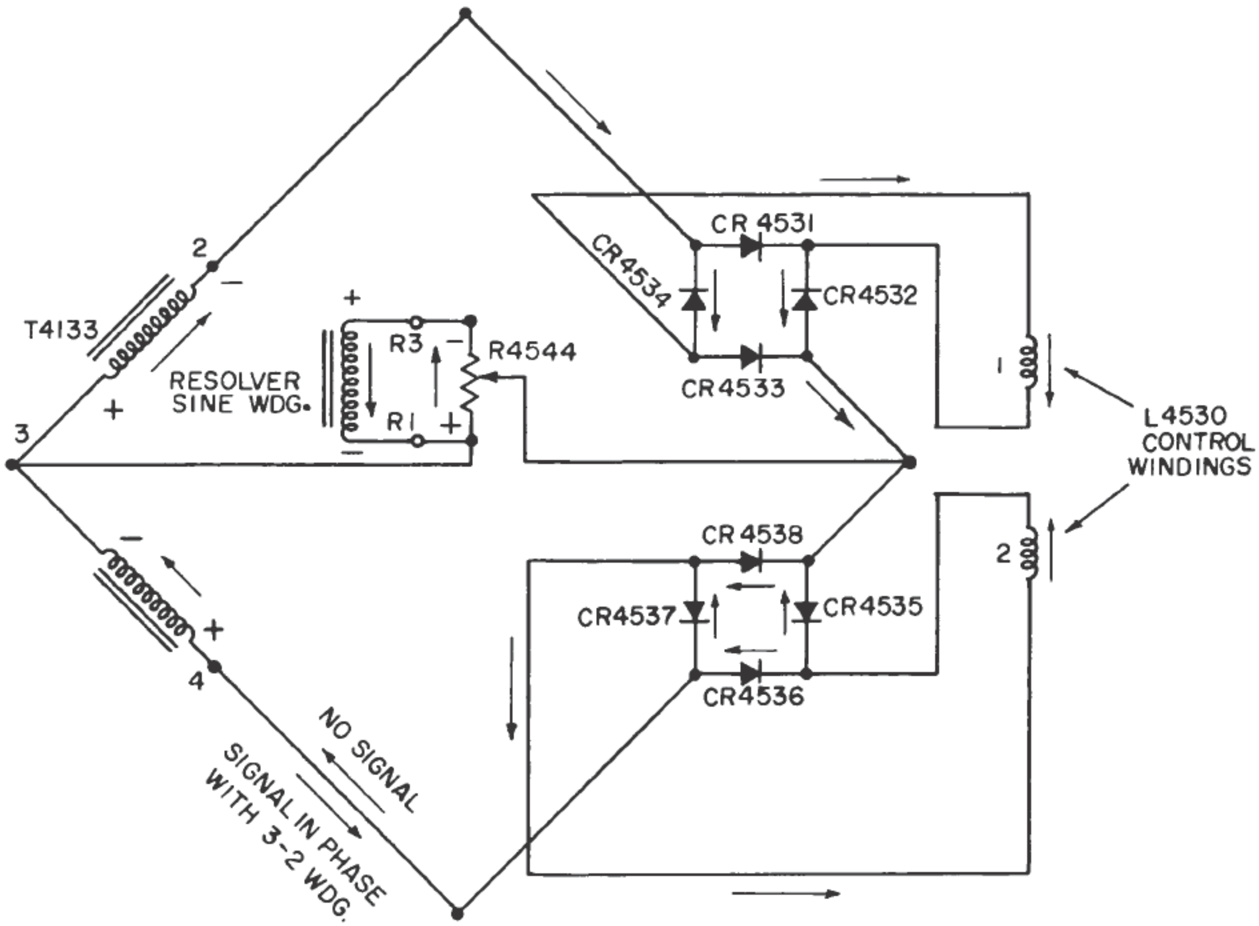

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Figure 5-11.—A channel demodulator, simplified schematic.

currents remain the same as for the first half cycle. Thus with no signal from the resolver the control winding currents are equal and opposite.

A signal output from the resolver will add to one section of T4133 and subtract from the other, depending upon the phase of the signal, thus unbalancing the control winding currents. When the resolver signal is in phase with the voltage of the 3-2 section as shown, the rectified outputs of CR4534 and CR4532 increase the control winding 1 current by an amount equal to the signal. At the same time the outputs of CR4537 and CR4535 reduce the control winding 2 current by an amount equal to the signal. A signal of the opposite phase will increase the control winding 2 current by an amount equal to the signal, and decrease the control winding 1 current by an amount equal to the signal. Thus the phase of the signal voltage determines which control winding predominates, and the magnitude of the signal voltage determines the strength of the predominate winding.

PREAMPLIFIERS.—The preamplifier stage (fig. 5-10, part 2) consists of push-pull, single-phase, full-wave magnetic amplifiers of the self-saturating type. The two outputs from the demodulator are fed to the preamplifier rectifier reactor L4530. Each input drives both amplifiers in opposite directions. The positive input drives the positive amplifier toward saturation and a higher output and it drives the negative amplifier

toward cutoff. The negative input drives the positive amplifier toward cutoff and the negative amplifier toward saturation.

When the signal is zero the demodulator outputs are both the same. The equal currents flowing in opposite directions in the control windings of the preamplifier create equal and opposite magnetizing forces in the preamplifier cores. These magnetizing forces neutralize each other and hence do not affect the preamplifier output.

When a signal is applied, the magnetizing forces no longer balance each other and the amplifier responds to the difference of these two forces. A positive signal causes the positive demodulator output to become larger which, in turn, causes the positive preamplifier output to become larger and the negative preamplifier output to become smaller.

Separate bias controls are provided for the two push-pull amplifiers. The bias current is normally zero or very small for operation at the saturation end of the operating range. Increasing the preamplifier bias will increase the preamplifier gain but it may cause system instability.

A negative feedback winding (current feedback) is provided on the preamplifier reactors to improve linearity of the system. Stabilizing windings also in the preamplifier (voltage feedback) are used to prevent oscillations which would otherwise be caused by the current feedback for improving linearity.

Without the current feedback the gain of the system from the preamplifier to the generator output would be very high. A small signal output from the resolver (less than 10 degrees of heading) would result in maximum generator output. In addition, the output versus input characteristic would not be linear nor would the output remain constant with voltage, frequency, and ambient temperature variations. Thus current feedback is added to make the system linear and independent of voltage, frequency, and ambient temperature variations. Current feedback signals proportional to the degaussing coil currents are obtained from a shunt in series with the degaussing coils. These signals are fed back as negative feedback to the A and FI-QI preamplifiers (fig. 5-10, part 2). Resistors R4553 and R4453 are used to adjust the amount of current feedback for the A and FI-QI preamplifiers respectively.

The voltage feedback circuit senses any change about to be made in generator output and acts to reduce system response to the change, thereby increasing system stability.

Voltage feedback signals are obtained from adjustable resistors across the outputs of the power amplifiers (fig. 5-10, part 3). These signals are fed back as negative feedback to the preamplifiers. The amount of signal fed back depends upon the rate of change of the generator field currents. No signal is fed back when the generator fields are constant as the d-c is blocked by capacitors C4537 and C4538 (A channel) and C4437 and C4438 (FI-QI channel). Reactors L4542, L4543, L4442, and L4443 in series with the generator fields reduce the transformer effect between the field windings, thus preventing circulating currents back through the voltage feedback circuits.

Since the FI-QI coil is used only to correct for induced magnetism, the available perm bias windings in the FI-QI channel preamplifiers are not used. However, the perm bias windings on the A channel preamplifier reactors are energized with a d-c voltage that is controlled by the AUTOMATIC AP ADJUSTMENT (R4542) and the AP POLARITY SWITCH (S4533).

POWER AMPLIFIERS.—Compare figure 5-8 with part 3 of figure 5-10 in order to observe the similarity of circuitry for the A channel and for the FI-QI channel. Each power amplifier stage consists of push-pull, single phase, full wave magnetic amplifiers of the saturable type. Power amplifier reactors L4537 and L4538 receive two outputs from the preamplifiers. The two power amplifier outputs in each channel's power stage are supplied to respective pairs of field windings in their respective degaussing generators.

TROUBLE LAMP AMPLIFIERS.—The trouble lamp amplifiers (fig. 5-10, part 2) consist of two half-wave magnetic amplifiers having parallel outputs which operate trouble indicator lamps. The demodulator outputs from separate rectifiers are fed to two opposing control windings and the perm bias signal is fed to a third winding. The total magnetizing force from these windings is proportional to the desired degaussing current. A signal proportional to the actual degaussing current, supplied by the current feedback circuit, is fed to another winding. If the degaussing current is of the correct value the magnetizing force from the current feedback winding will be equal and opposite to the magnetizing force produced by the three signal windings, and the trouble indicator lamps will not be

energized. If the degaussing current is different from the desired value the magnetizing forces will be unbalanced and one of the two parallel amplifiers (depending upon the polarity of the error) will conduct and energize the trouble indicator lamps. The bias current is adjusted so that the indicator lamps will light when the error reaches five percent of rated degaussing current.

FP-QP and M Channels

The required currents in the FP-QP and M coils are not affected by changes in the ship's heading, hence the polarity and magnitude settings for these coils are made only by manual controls. Since the two channels are quite similar, only the M channel components will be identified below.

The circuitry (fig. 5-7) is relatively simple for the M coil requirements when compared with the circuit requirements previously discussed in figure 5-10. Both channels (FP-QP and M) are designed to hold a fairly constant output current after they are manually set for the specified degaussing currents, despite voltage and frequency variations. The amplifiers are of the nonself-saturating type and are designed so that the output of each stage is proportional to the input and, within limits, the output current is not affected by voltage and frequency variations.

In the M coil channel (fig. 5-7), three-phase power is supplied through safety interlock contactor K1201 and circuit breaker S1202 (both in fig. 5-7, part 1) directly to the output windings of the power amplifier reactors (L2207, L2208, and L2209, see part 2). No power transformer is used between the power amplifier reactors and the POWER TRANSFER SWITCH. The output from the power amplifier is applied to the power rectifiers, then to the polarity reversing contactor K2202 and the M degaussing coil (see part 3 of fig. 5-7).

Power from one phase of the 440-volt, 60-cycle line is applied to the control power autotransformer T1201 (part 1) that feeds the current-adjustment transformer (T1206) by way of the constant-voltage transformer (T1203).

OPERATION

The FI-QI and A coils may be operated in either automatic or emergency manual control. The FP-QP and M coils can only be operated manually. Operation of the FI-QI and A coils is presented below.

Automatic Operation

Operating the FI-QI and A coils for automatic control requires reference to figures 5-1 and 5-2. Set the AUTOMATIC TEST SWITCH to its OPERATE position. Turn the H-ZONE SETTING switch to the position obtained from the ship's degaussing folder, in accordance with the ship's geographical location. Loosen the MAGNETIC VARIATION CONTROL, and turn this control knob to the magnetic-variation value which is determined from the ship's navigational charts. Relock the MAGNETIC VARIATION CONTROL.

NOTE: Do not disturb the automatic FI-QI adjustment, automatic AP adjustment, or automatic AI adjustment controls during operation. Their adjustments are made only during calibration procedures. Energize the FI-QI coil's a-c motor by setting the FI-QI TRANSFER SWITCH to NORMAL or ALTERNATE position, and set the FI-QI COIL MOTOR CIRCUIT BREAKER to ON. Next, push the FI-QI COIL START (FIELD OVERLOAD RESET) button to start its motor-generator set. The MOTOR RUNNING indicator lamp should light.

Energize the automatic units by setting the 400-CYCLE 120-VOLTS CONTROL POWER AND GYRO SIGNAL switch to ON. The 400-CYCLE power indicator lamp should light.

Set the 120-VOLTS 60-CYCLES switch to ON. The indicator lamp above that switch and the FI-QI COIL AUTOMATIC OPERATION lamp on the remote panel should light.

Check the FI-QI COIL TROUBLE indicator lamp on the switchboard and remote panel. If lit continuously, the FI-QI channel is defective, and must be shut down for repairs.

For automatic control of the A coil, set the A COIL TRANSFER SWITCH to AUTOMATIC. Set the POWER TRANSFER SWITCH TO NORMAL or ALTERNATE position. Set the A COIL MOTOR CIRCUIT to ON. Push the A COIL START (FIELD OVERLOAD RESET) button on the switchboard to start the A coil motor generator set. The MOTOR RUNNING lamp should light. Set the 400-CYCLE 120-VOLTS CONTROL POWER AND GYRO SIGNAL switch to ON. The 400-cycle POWER ON indicator should light. Set the 120-VOLTS 60-CYCLES switch to ON. The indicator lamp above that switch and the A COIL AUTOMATIC OPERATION lamp on the remote panel should light. Now check the A COIL TROUBLE indicator lamp on the switchboard and remote panel. If lit continuously, the A coil automatic channel is defective, and must be shut down for repairs.

Emergency Manual Operation

The A or FI-QI channels may be put into manual operation by turning the respective TRANSFER SWITCH (S4434 or S4534 fig. 5-10, part 3) to MANUAL. The TRANSFER SWITCH when turned to the MANUAL position disconnects the 400-cycle supply, the heading assembly, and the magnetic amplifiers from the channel concerned. The degaussing current is then controlled manually.

The rectifiers in the power amplifiers are reconnected as a conventional single-phase bridge to supply the generator fields during manual operation. Power for the coils in manual operation is supplied by the 60-cycle power transformer T4134, (fig. 5-10, part 3). The input to the rectifiers in the A channel comes from adjustable autotransformers T4536 and T4537 (fig. 5-10, part 3). The output of T4536 may be connected to either of the two power amplifier rectifiers by a section of the AP POLARITY SWITCH, S4533.

Voltage for the manual AI adjustment (T4537), and the manual FI-QI adjustment (T4437) is supplied from one of the taps on T4134 as selected by the H ZONE SETTING SWITCH, S4131. The output of T4437 is applied to one of the FI-QI power amplifier rectifiers, and the output of T4537 is applied to one of the A power amplifier rectifiers, as selected by the EMERGENCY MANUAL SWITCH, S4111, or S5111 if LOCAL REMOTE SWITCH, S4135 is in the REMOTE position. The selection of the positive rectifier, negative rectifier, or off, by S4533, roughly approximates the sine and cosine functions required for ideal degaussing currents.

Operating Adjustments

The adjustments which can be performed on the automatic degaussing equipment may be divided into three groups: alignment, calibrating, and routine operating adjustments.

ALIGNMENT ADJUSTMENTS.—All alignment adjustments are made at the factory and are securely tightened or locked. These alignment controls, none of which are located at the front panels of the switchboard or the remote panel, should normally not be disturbed.

Alignment adjustments may be necessary after a complete overhaul or replacement of major components. These adjustments are described in the manufacturer's technical manual and include the following adjustments: (1) maximum and minimum degaussing coil currents; (2) trouble lamp amplifier, preamplifier, and demodulator adjustments; (3) voltage reference circuit adjustments; (4) stabilization feedback adjustments, and (5) heading assembly alignment.

CALIBRATING ADJUSTMENTS.—Controls for these adjustments are located on front and back of doors of the switchboard and the automatic control unit. Follow the exact procedures as listed with supplementary drawings and detailed illustrations in the manufacturer's technical manual for the location, function, and proper use of these controls.

Under identical conditions of location and heading, different ships will require different degaussing currents to compensate properly for their induced magnetism. The AUTOMATIC FI-QI ADJUSTMENT, (R4444) and the AUTOMATIC AI ADJUSTMENT, (R4544 fig. 5-10, part 1) are provided for the adjustment of the overall gain of the respective channels and permit the degaussing currents to be set at levels which are most effective for the individual ship.

ROUTINE ADJUSTMENT.—The routine adjustments are made in the daily, automatic and manual operation of the degaussing equipment are classed as operating adjustments. They involve the use of the operating controls located on the front panels of the switchboard, the automatic control unit, and the remote panel. They are provided with locking devices to prevent accidental disturbance of setting. To adjust this type of control, turn the large knurled, or hexnut counterclockwise, then set the control for the desired value and securely relock the control in position by turning the nut clockwise.

MAINTENANCE

The Type GM-1A Automatic Degaussing Equipment is a ruggedly constructed assembly of electrical materials. It contains no electronic tubes and the circuit elements in general will not need replacement because of wear. However, the many precautions that apply for maintenance of all shipboard electrical systems are emphatically needed here.

First and always, bear in mind that this equipment is energized with dangerous voltages. Instruct all electrical maintenance personnel to observe the safety precautions and purposes for electrical maintenance procedures as presented in chapter 60 of Bureau of Ships Technical Manual.

To maintain optimum performance of the equipment and degaussing system, keep the insulation resistance of degaussing coils and of the system's circuits at high values as instructed in Electricians Mate 3 and 2, NavPers 10546 (revised). To achieve and retain the high resistance values keep the parts clean and dry. Avoid opening the front hinged panel of an enclosure when repairs, sweeping, or other operations likely to stir up dust and spray are performed in the vicinity of the equipment. Check and make certain that all electrical connections are tight.

When cleaning interior parts of the equipment, first disconnect all power. Clean interior parts only with a dry cloth, a soft brush, a hand bellows, or a vacuum cleaner. Never use a damp or wet cloth to clean wiring.

Corrective maintenance is performed after disclosure of a defective part (or parts) by means of 3 progressive steps. The first step consists of using the alarm bell and panel indicator lamps on the automatic control unit, switchboard, or remote panel to sectionalize the trouble to a particular channel. The second step is to locate the probable cause with the aid of trouble shooting tables in the manufacturer's manual. The third step is to verify the probable cause (chosen in step 2) by the use of external test equipment and effect a remedy as given also in the referenced trouble shooting tables. Amplifier troubles may be detected by plotting output curves.

DEGAUSSING FOR MINE WARFARE SHIPS

The extremely low field requirements for mine warfare ships necessitates special ship design, proper control and stowage of magnetic materials, and degaussing protection that maintains accurately regulated currents at any angle of roll, pitch, and heading.

Four basic types of degaussing coils are installed in mine warfare ships (fig. 5-12). The M, or main coil, is located in a horizontal plane and compensates for the induced vertical magnetism of the ship. The A, or athwartship coil, is located in a vertical fore and aft plane and compensates for the induced athwartship magnetism of the ship. The L, or longitudinal coil, is located in a vertical athwartship plane and compensates for the induced longitudinal magnetism of the ship.

Each M, A, and L coil has an associated and identically located P, or perm coil (not shown) which compensates for the permanent portion of the ship's magnetism.

Mine warfare ships were initially provided with gyro controlled automatic degaussing control systems. A magnetometer controlled system has now been developed which is replacing the gyro controlled systems.

GEM-2 SYSTEM

The GEM-2 automatic degaussing control system (figs. 5-13 and 5-14) is a magnetometer controlled system that is replacing the gyro controlled GM-2 system used on coastal minesweeper ships (MSC) and coastal minehunter ships (MHC). The three-axis magnetometer probe assembly (fig. 5-15) is mounted near the top of the ship's mast, and continously measures the earth's magnetic field. The assembly (approximately 6''x6''x6'') consists of three identical sensing elements, positioned at right angles to each other. Each sensing element is positioned in the same plane as the degaussing coil it controls.

The GEM-2 system eliminates most objectional features of the GM-2 system. The possibility of operator error is greatly reduced as the manual H and Z zone settings are eliminated. After the ship is calibrated at a degaussing range, the controls may be locked in place, and the operator only turns the equipment on and off. Also eliminated are the mechanical servo and computer units that are subjects to failure in the GM-2 system.

The GEM-3 system, similar to the GEM-2, is installed on minesweeper boats (MSB).

EMS SYSTEM

An EMS magnetometer controlled automatic degaussing control system has been developed to replace the SM gyro controlled systems used on ocean minesweeper ships (MSO). This system utilizes transistors with printed circuits and static type power supplies.

The three main units of the system are the magnetometer probe assembly, the magnetometer signal amplifier panel, and the control panel.

Magnetometer Signal Amplifier Panel

The magnetometer signal amplifier panel contains three (M, A, and L) signal amplifier subassemblies, three error amplifier subassemblies, three fault logic amplifier subassemblies, and three milligauss meters.

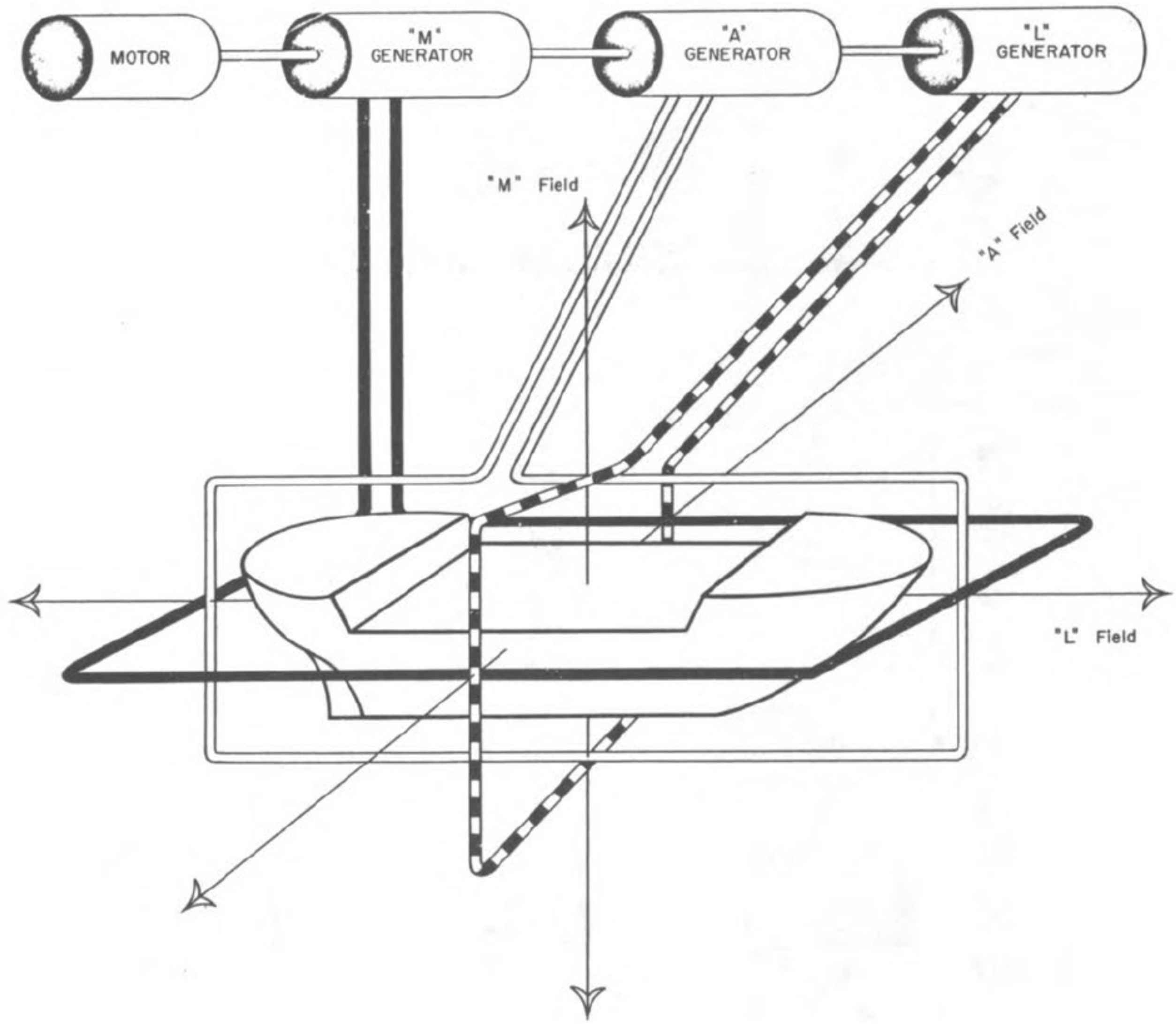

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Figure 5-12.—M, A, and L degaussing coils.

Signal Amplifier Subassembly.—The signal amplifier subassembly (fig. 5-16) includes a three-stage a-c transistor amplifier, a signal demodulator, and a three-stage d-c amplifier. These units amplify the signal from the magnetometer and convert it to a d-c signal proportional to the magnetometer field strength.

Error Amplifier Subassembly.—The error amplifier subassembly is similar to the signal amplifier subassembly. The input signals are supplied from the magnetometer error sensing element. The output is fed to the fault logic subassembly where it operates the excess error light when its output is not zero.

Fault Logic Subassembly.—The fault logic subassembly includes a two-stage amplifier with a relay in the output circuit. The inputs to the amplifier are such that the amplifier cuts off and

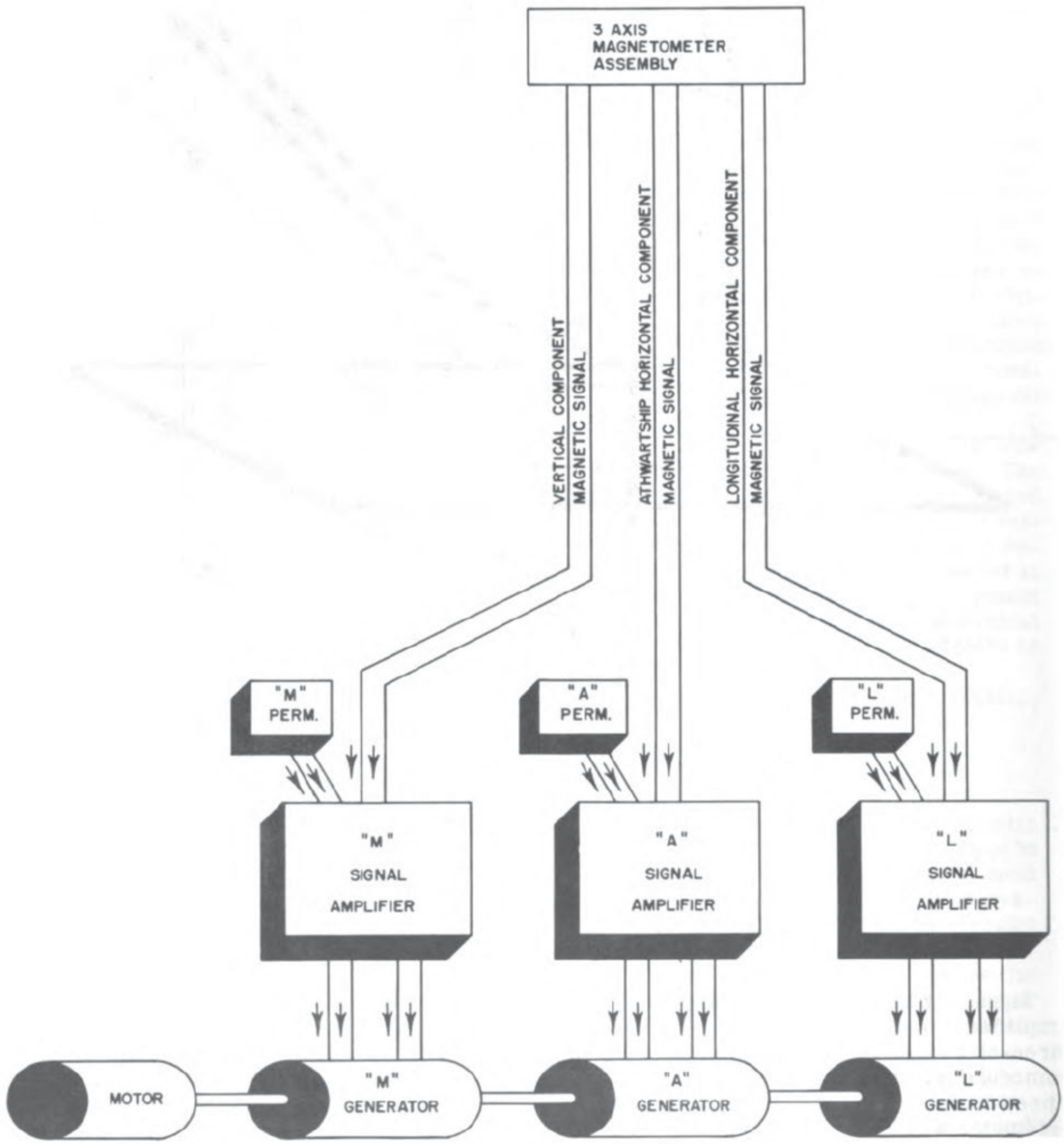

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Figure 5-13.—Block diagram of GEM-2 automatic degaussing control system.

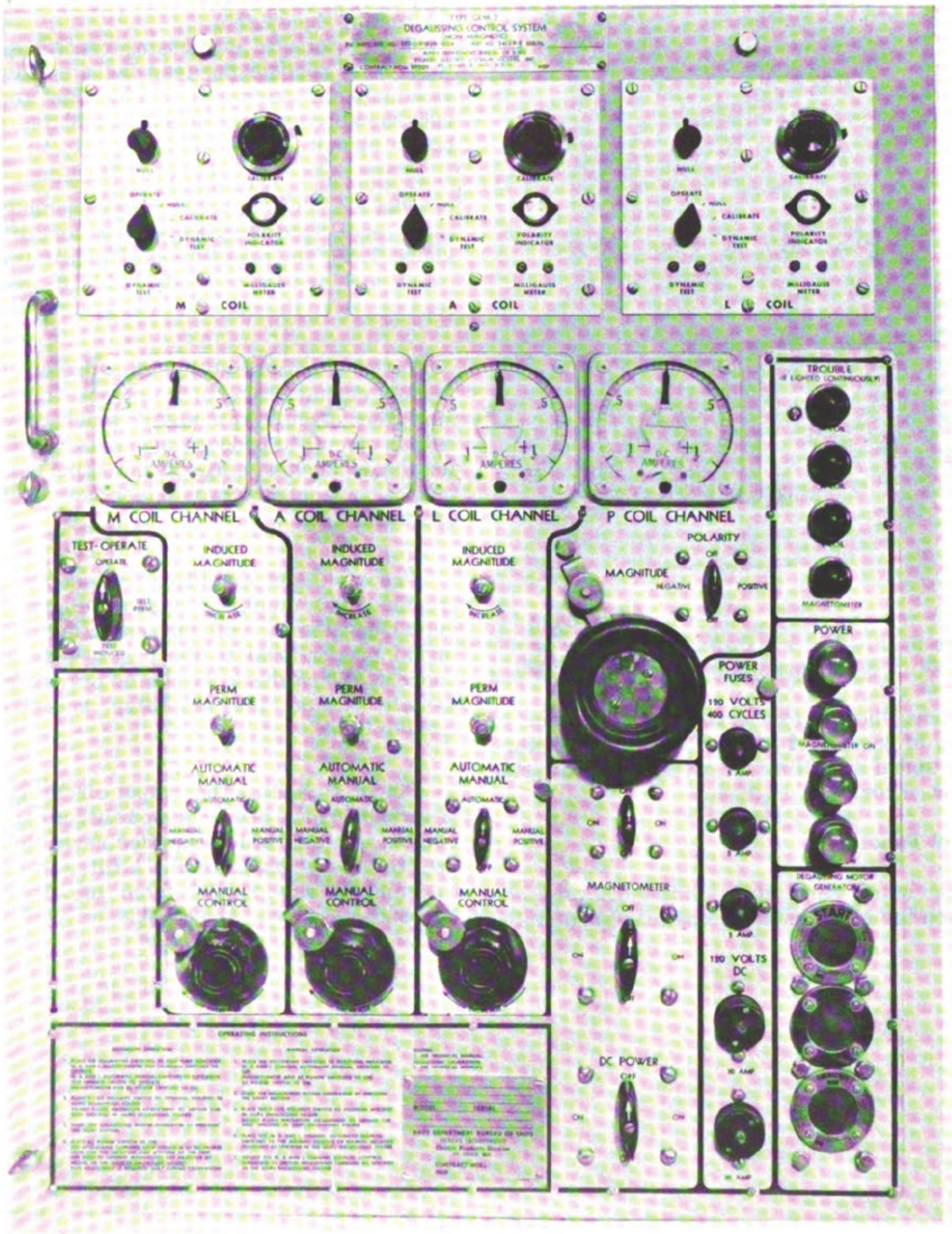

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Figure 5-14.—Front panel of control unit for GEM-2 automatic degaussing control system.

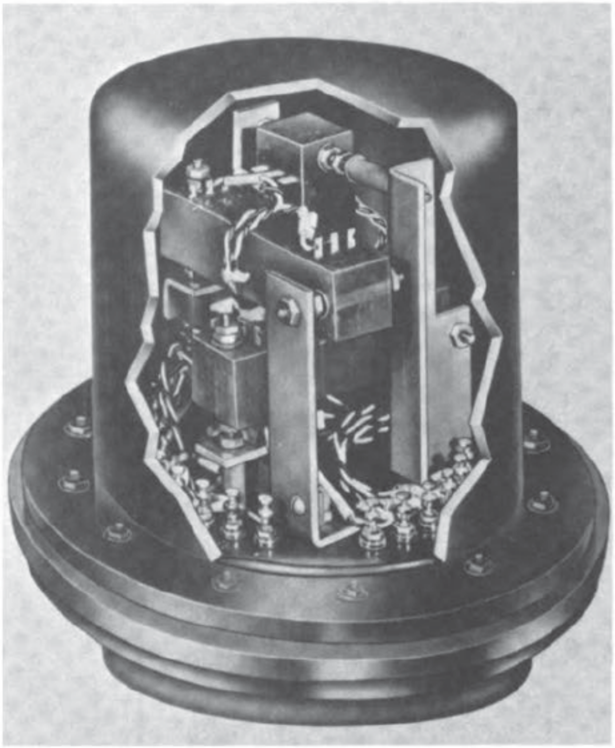

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Figure 5-15.—Three-axis magnetometer probe assembly.

energizes the excess error light in case of failure of the d-c, 1-kc, or 2-kc power, failure of any signal amplifier, or excessive degaussing current error.

Control Panel

The control panel contains five drawers, one for each the M, A, and L automatically controlled channels, one for the manually controlled P coil channel, and a test drawer which provides means for testing the system.

The automatic degaussing control drawers (fig. 5-17) include the lead lag amplifier subassembly and associated trouble light amplifier subassembly, two driver subassemblies, and the output circuit.

The Lead Lag Amplifier Subassembly.—The lead leg amplifier subassembly amplifies the signal from the magnetometer signal amplifier panel and applies a predetermined amount of lead or lag to the output of the system.

Driver Subassembly.—The driver subassembly circuit converts the output of the lead lag amplifier circuit to a signal which drives the output circuit to produce the necessary current for the degaussing coil. As the output is a push-pull arrangement, two driver subassemblies are used.

Trouble Light Amplifier Subassembly.—The trouble light amplifier circuit compares the actual degaussing coil current with the control signal proportional to the required degaussing current. When these signals do not agree within certain limits, the amplifier energizes the trouble light.

Output Circuit.—The output circuit consists of a single-phase center tapped silicon controlled rectifier circuit which supplies reversible current to the degaussing coil. A filter is included to remove any ripple from the degaussing current.

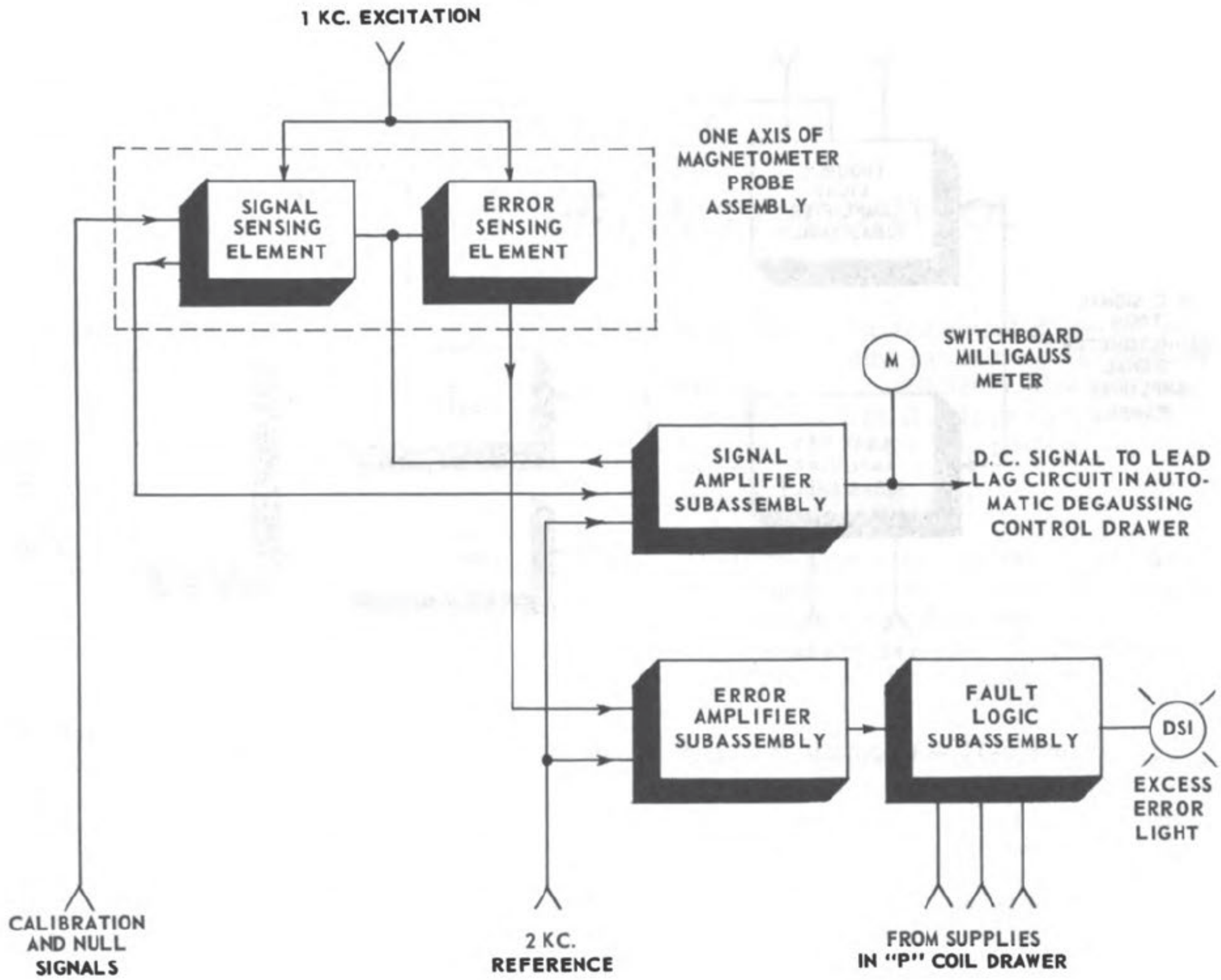

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Figure 5-16.—Magnetometer and magnetometer signal amplifier panel, simplified block diagram.

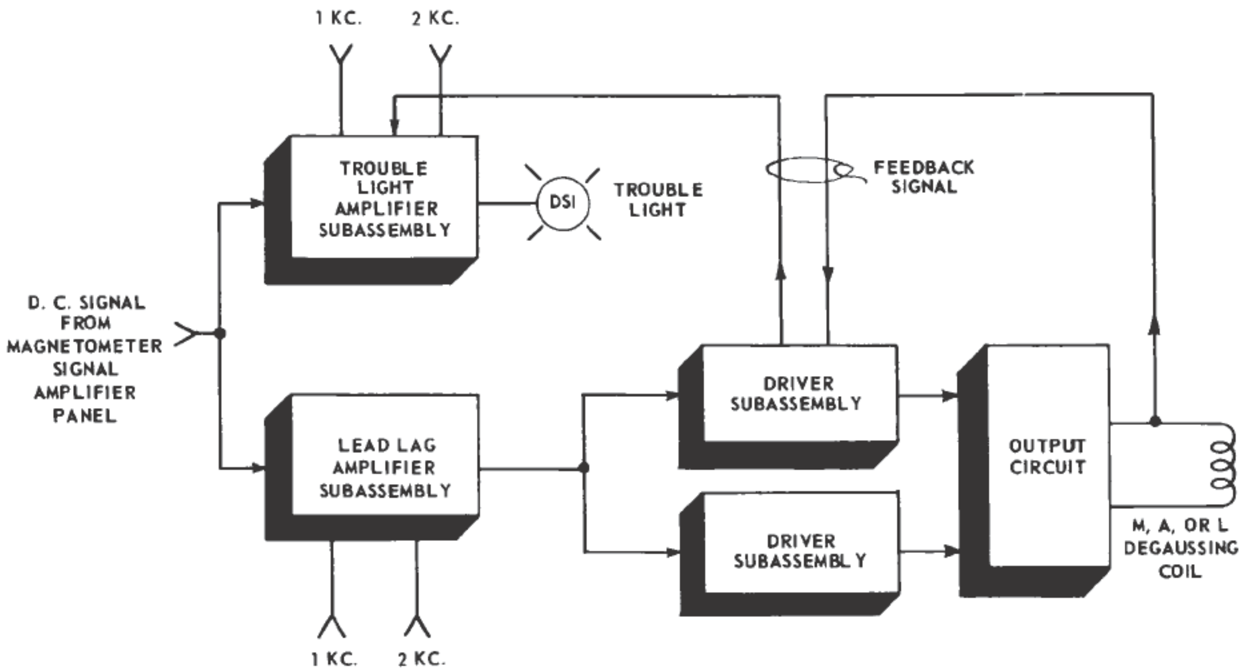

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Figure 5-17.—Automatic degaussing control drawer, simplified block diagram.

CHAPTER 6

ENGINEERING CASUALTY CONTROL

The operating efficiency of a ship depends largely on the ability of the ENGINEERING DEPARTMENT to continue its services both during normal operations and during a CASUALTY to any part of the ship. Engineering casualty control is concerned with the prevention, minimization, and correction of the effects of operational and battle casualties as outlined in section 3 of chapter 9880 of BuShips Technical Manual.

This chapter describes the broad aspects of engineering casualty control, including casualties of the machinery, electrical, and piping installations aboard ship. The text and illustrations are based on the DD445/692/710 class of destroyers. Refer to the Casualty Control Manual prepared by the type commander for details concerning engineering casualty control instructions for your class of ship.

Although the Electrician's Mate is not responsible for machinery other than that driven by electric power, a general knowledge of the main propulsion and auxiliary plants will enable him to acquire a better understanding of the overall system.

The chapter also includes material concerning a-c and d-c electric drive casualties. The Fleet Tug diesel electric d-c drive, and the Destroyer Escort turboelectric a-c drive are used as representative systems.

MISSION OF CASUALTY CONTROL

The mission of casualty control is the maintenance of all engineering services in a state of maximum reliability under all conditions of operation. Failure to provide all normal services will affect the ship's ability to function effectively as a fighting unit, either directly by reducing its mobility, offensive and defensive power (including the ability to control fire, flooding, hull, and armament damage), or indirectly by reducing habitability and thus, personnel morale and efficiency. Casualty control can be divided into the (1) prevention, (2) correction, and (3) restoration phases.

CASUALTY PREVENTION

Casualty prevention is the most effective phase of casualty control. It concerns the preventive maintenance of machinery and systems to counteract the effects of operational and battle casualties. Proper preventive maintenance will greatly reduce the occurrence of casualties caused by material failures. Continuous detailed inspection procedures are necessary to disclose not only partially damaged parts that may fail at a critical time, but also to eliminate the underlying conditions, including maladjustment, improper lubrication, and corrosion, which are detrimental to machinery and cause early failure.

CASUALTY CORRECTION

Casualty correction concerns the correction of the effects of operational and battle damage to minimize the effect on the mobility and offensive and defensive power of the ship. This phase consists of the action taken at the time of the casualty to prevent future damage to the affected unit and to prevent the casualty from spreading through secondary effects.

The speed with which corrective action is applied to an engineering casualty is often of paramount importance. The extent of the damage must be thoroughly investigated and reported to the engineer officer. The engineer officer must be informed at all times of the condition of his plant in order to maintain maximum available speed and services.

The commanding officer has the responsibility of deciding whether to continue operation of

equipment under casualty conditions with the possible risk of permanent damage. Such action can be justified only when the risk of even greater damage or loss of the ship may be incurred by immediately securing the affected unit.

CASUALTY RESTORATION

Casualty restoration concerns making the necessary repairs, which will completely restore the installation to its original condition.

If the damage incurred to equipment is beyond the repair facilities of the forces afloat, the ship will probably be sent to a naval shipyard before returning to service. In this case, the salvage efforts of the crew must ensure that no additional deterioration of equipment will occur between the time of beginning operations and arrival at the yard.

ENGINEERING CONDITIONS OF READINESS

The purpose of engineering conditions of readiness is to establish standards of material readiness in the engineering department for the various conditions of operation of the main propulsion units, and auxiliary machinery. The required engineering conditions of readiness are conditions 1 through 4.

MAIN PROPULSION UNITS

The factors that determine the readiness condition of the main plant are the (1) number of boilers in use and the standby condition of the remaining boilers, and (2) whether the main plant is split or cross connected. The four readiness conditions are defined in terms of these factors for DD692 class destroyers.

CONDITION 1 utilizes four boilers with the main plant split. Boilers 1 and 3 supply auxiliary steam to the starboard lines, and boilers 2 and 4 supply auxiliary steam to the port lines. This condition of readiness must be used at general quarters and on ships having both electric and steam pumps. The steam pumps should be used with the electric pumps lined up in standby condition.

CONDITION 2 utilizes two boilers with the main plant split. The remaining two boilers should be boosted to assure readiness within one hour. This condition of readiness should be used in a war zone when attack is probable.

CONDITION 3 utilizes two boilers with the remaining boilers secured but completely operational within two hours. The main plant can be split or cross-connected to conform with security requirements. However, the main plant must be split under war conditions, when entering or leaving port, or steaming in restricted waters and in heavy weather.

CONDITION 4 utilizes boiler and turbine combinations for the best fuel economy to conform with operational requirements. The remaining boilers should be available within eight hours.

The main and auxiliary steam systems are shown in figures 6-1 and 6-2.

AUXILIARY MACHINERY

The readiness of auxiliary machinery consists of the readiness requirements of the turbo generators, diesel generators, refrigeration plant, and the main drain system for the various conditions of readiness. The classification of valves and fittings in the auxiliary systems for setting material conditions are contained in the Damage Control Book.

Both TURBO GENERATORS must be used with the electrical load split when in condition 1 or condition 2, and under circumstances when split plant is required in condition 3. In condition 1 both turbo generators must exhaust to their auxiliary condensers. When both generators are in use during general quarters and battle conditions, the electrical load must be split by opening the a-c and d-c bus-tie circuit breakers on both the forward and after ship's service switchboards.

The DIESEL GENERATORS must be set up for full automatic operation at all times except when receiving shore power. The fully automatic operational condition of the diesel generators must be maintained during nuclear, biological, or chemical attack. Positive ventilation must be assured to the diesel generator rooms during these attacks. Blowers must be turned off, but vent ducts must remain open to prevent suffocation of personnel when the diesel engine starts. Personnel in these spaces are required to wear gas masks and protective clothing.

The REFRIGERATION PLANT must be secured for Condition 1 and reenergized as necessary to preserve food. Salt-water supply valves to the refrigeration condensers should be classified, red circle Z.

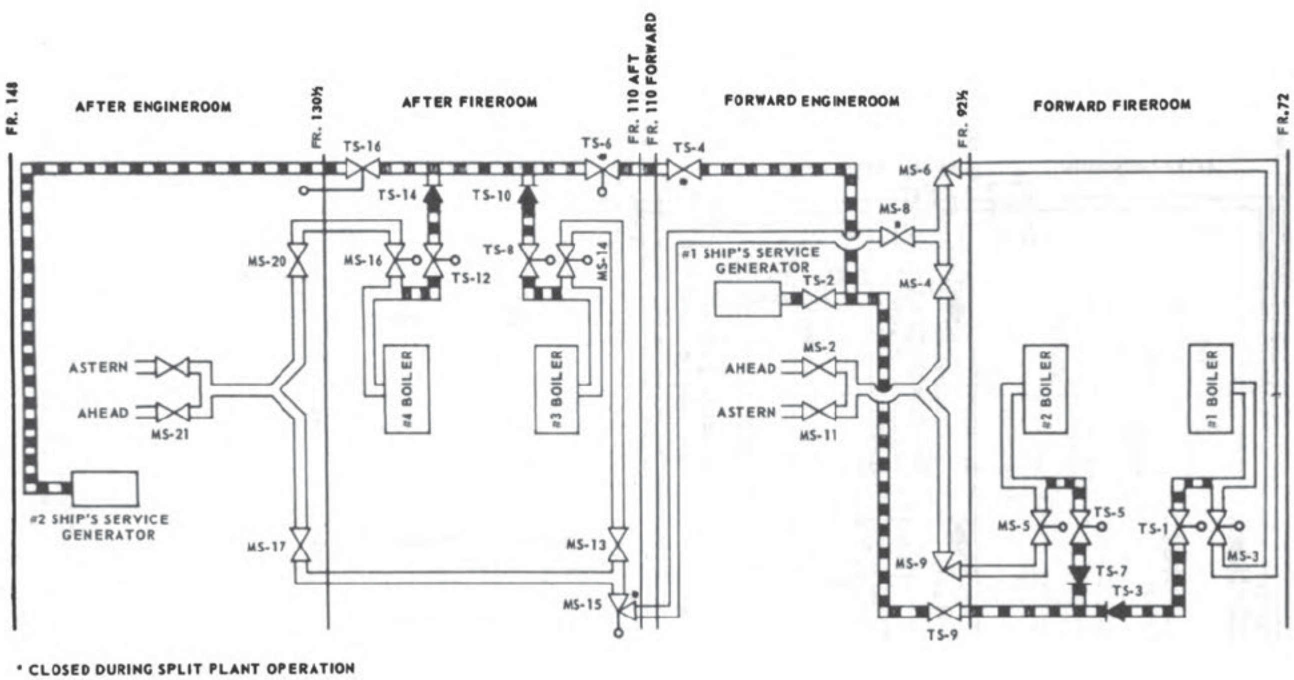

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Figure 6-1.—Main steam system.

The MAIN DRAIN SYSTEM for condition 1 consists of lining up fire and bilge pumps 1 and 3 (forward and after firerooms) to discharge to the firemains (fig. 6-3).

Fire and bilge pumps 2 and 4 (forward and after enginerooms) are turning over slowly on sea suction and discharging to the sea. In this condition the pumps can be placed rapidly on the firemain or bilge suctions.

The bilge suction valves in each space must be left open at all times, especially for condition 1. Bulkhead cutout valves must be closed except when pumping on an adjacent space.

CASUALTY CONTROL ORGANIZATION

The speed with which corrective action is applied to an engineering casualty depends on effective personnel organization and constant training.

WATCH TEAMS

The basic organization for engineering casualty control is the watch team in each machinery space. Three watches are required for each of the steaming spaces.

The watch teams must be thoroughly organized with each man assigned his duties for watch standing, including each casualty control procedure, fire, flooding, and setting of material conditions. The petty officer in charge of each team must maintain complete control to avoid confusion, which will disrupt the organization and coordination of his team.

The dissemination of information to all stations is extremely important in the effective control of engineering casualties. It is essential that the engineer officer receive brief, clear, and concise information from all stations to properly administer the operation of the engineering plant and to promptly order corrective measures for the control of casualties.

The sound-powered telephone (circuit 2JV) is the principal means of transmitting this information efficiently. The telephone talker has an important job. He is the key to good communications. If a message is not relayed promptly and correctly, it may place the ship in danger. In battle, the safety of the ship and the crew depends on how well the talker uses his voice and

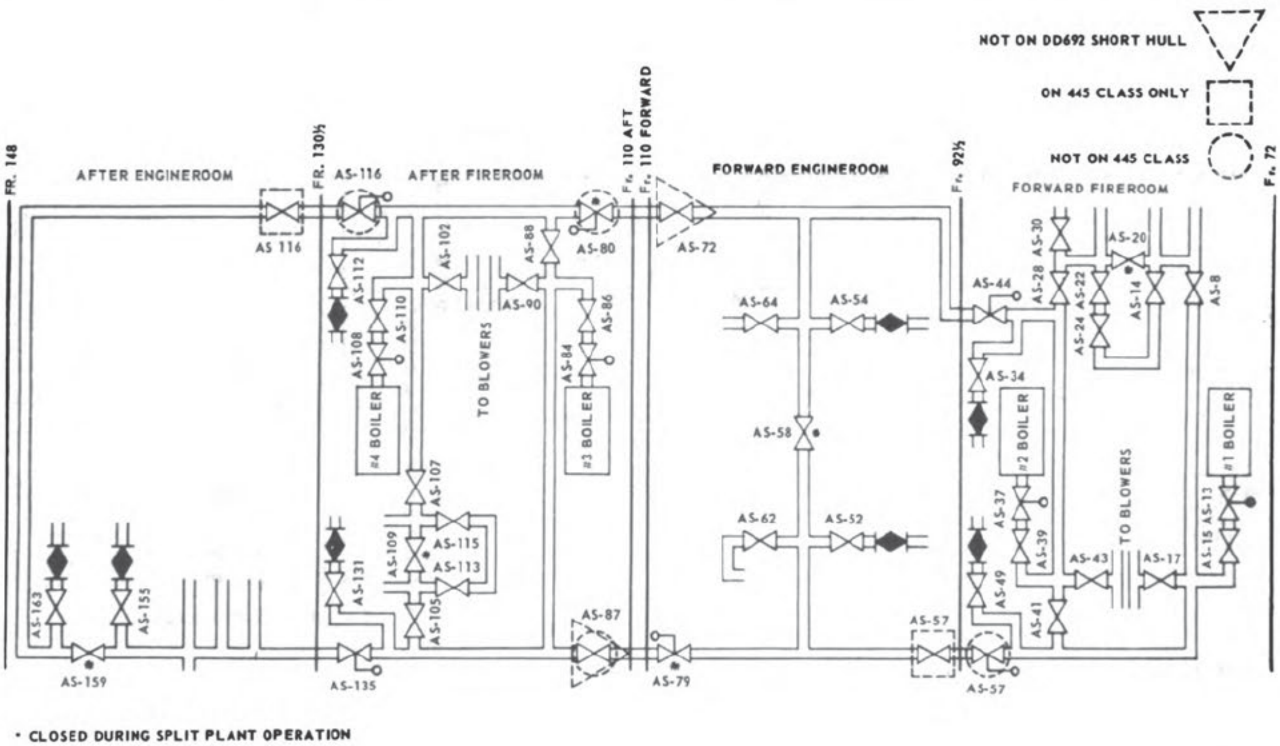

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Figure 6-2.—Auxiliary steam system.

equipment. The importance of officers and petty officers being proficient in the use of proper engineering terms and phraseology cannot be overstressed. It is not the responsibility of the talker to decipher, translate, or rephrase improperly transmitted orders. This is the responsibility of the person issuing the order or originating the message. It is the duty of the talker to relay the message as given.

Casualty Control Phraseology

Standard phraseology will greatly enhance communications both within and between teams. It minimizes confusion by reducing the amount of conversation so that transmissions are easily relayed and understood. When practicable, one command should initiate a whole casualty procedure. It is much more effective within the team and between teams to pass the command, "cross-connect the plant," or "cross-connect main feed port side," than "open valves main steam 15, main steam 8, auxiliary steam 79 and 80, auxiliary feed 44, and so on."

If the command from main engine control is "cross-connect main feed starboard side," the petty officers in charge of No. 1 and No. 2 firerooms would repeat "cross-connect main feed starboard side." The men already assigned this procedure would open valves, MF-3 and MF-37 (fig. 6-4), with no further command. The men should report back when a job is done because the engineer officer must often wait for a report before giving another command. The use of good talker procedure and standard phraseology will show immediate results.

CASUALTY CONTROL BOARD

The casualty control board (fig. 6-5) is essential for effective casualty control during battle conditions. It furnishes a complete picture of the machinery for the use of the engineer officer at general quarters and watch personnel during condition watches.

For optimum results, a casualty control board should be installed at the main engine control, the after engineroom, and at the main

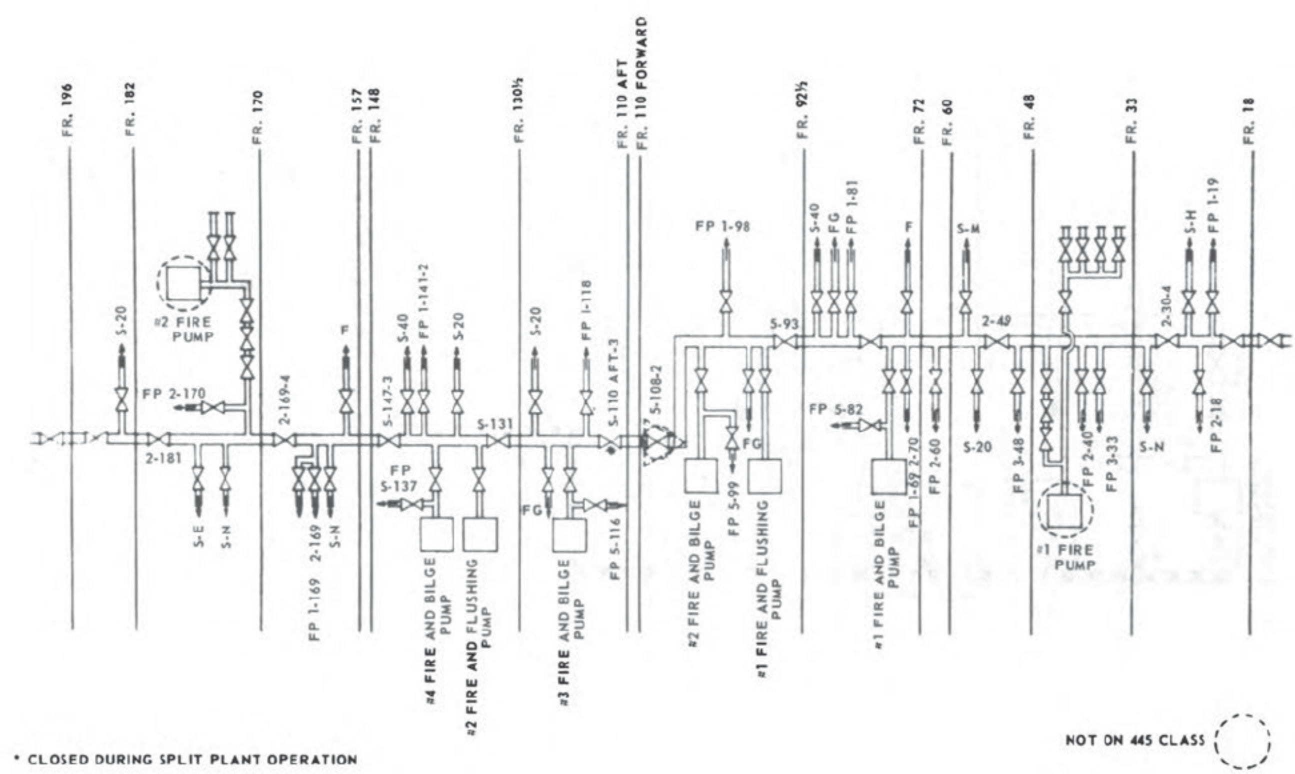

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Figure 6-3.—Fire main system.

propulsion repair party station. The 2JV talkers at these stations should be responsible for maintaining the boards. The status of machinery is indicated by marking the affected unit with a grease pencil on the plexiglass front of the casualty control board.

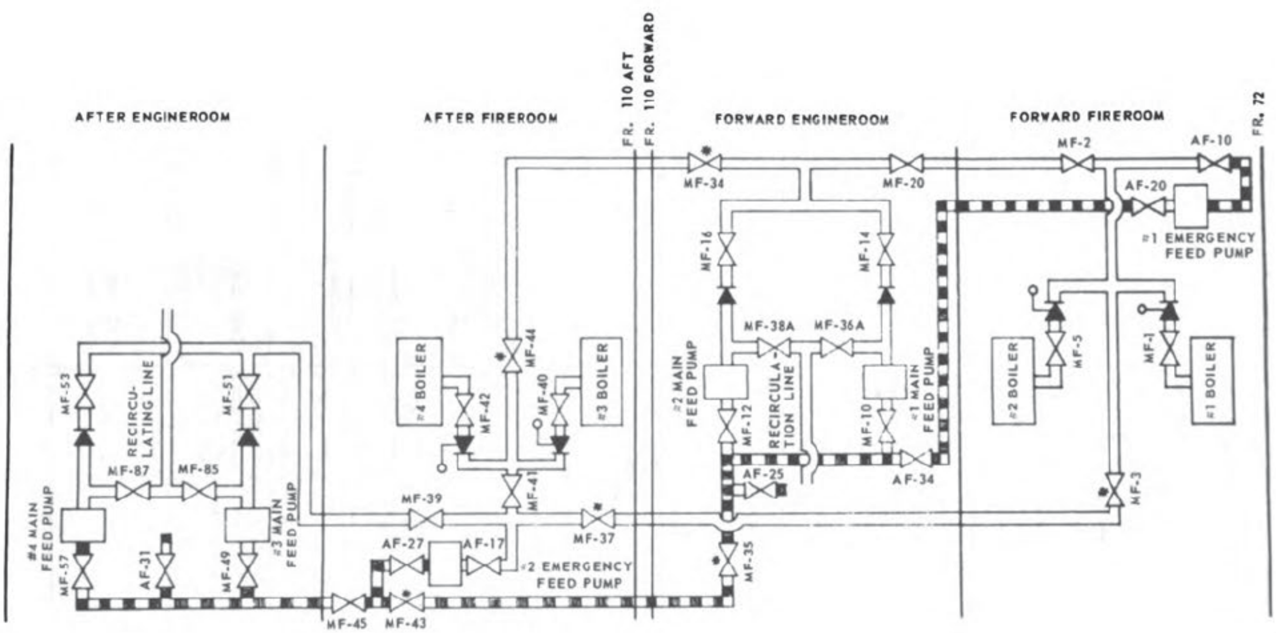
PROPULSION REPAIR PARTY

The engineering casualty control organization also includes the propulsion repair party, which is integrated into repair 5 (propulsion repair station). The personnel assigned must be specialists in main propulsion operation and repair as well as highly skilled in the overall field of damage and casualty control. Repair 5 must be so organized as to facilitate immediate securing of any or all propulsion spaces; to effect repairs to any steam piping or equipment; to station an underway watch and relieve the general quarters team in any propulsion space; and to evaluate and control any casualty or damage in that section of the ship for which it (repair 5) is responsible.

The personnel assigned to repair 5 for a destroyer with a full personnel complement, consist of the following:

Duty	Number	Rank or Rate
Electrical Officer	1	ENS
Machinery Repair	2	MMC and MM2
Boiler Repair	2	BTC and BT (any rate)
Auxiliary Repair	1	MM or MR (any rate)
Electrical Repair	1	EMC or EM1
Stretcher Bearers	2	MMFA and BTFA
Talker (2JZ)	1	MM3 or MMFN
Messenger	1	BTFA

In the event of damage requiring the abandonment of any machinery space, personnel



* CLOSED DURING SPLIT PLANT OPERATION

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Figure 6-4.—Main feed system.

abandoning the space must report to the officer in charge of repair 5 for assignment to duty.

The relationship between repair 5 and other repair parties appears in Military Requirements For Petty Officers 3 & 2, NavPers 10056-A.

Electrical officer (ENS) is in charge of the propulsion repair station. He is the evaluator, coordinator, and the relief for the officer in charge of main propulsion.

Machinery repair (MMC) is in charge of securing engineroom spaces, and effecting engineroom and auxiliary repairs. He is the relief for the CPO of the watch. The MM2 assists in securing engineroom spaces, and effecting engineroom and auxiliary repairs. He is the relief for the engineroom lower level watch.

Boiler Repair (BTC) is in charge of securing fireroom spaces and effecting fireroom repairs. He is the relief for the BT of the watch. The BT (any rate) assists in securing fireroom spaces and effecting fireroom repairs. He is the relief for the checkman.

Auxiliary Repair (MM or MR any rate) assists in securing engineroom spaces and auxiliary machinery, and effecting engineroom and auxiliary repairs. He is the relief for the throttleman.

Electrical Repair (EMC or EM1) is in charge of securing electrical power and circuits, rigging casualty power in the main propulsion spaces, and effecting electrical repairs. He is the relief for the electrical switchboard watch.

Stretcher Bearer (MMFA) assists in securing engineroom spaces, and effecting engineroom and auxiliary repairs. He is the relief for the engineroom messenger. Stretcher Bearer (BTFA) assists in securing fireroom spaces and effecting fireroom repairs. He is the relief for the burner watch.

The 2JZ Talker (MM3 or MMFN) correlates and transmits reports.

Messenger (BTFA) assists in securing fireroom spaces and effecting fireroom repairs. He is the relief for the fireroom messenger.

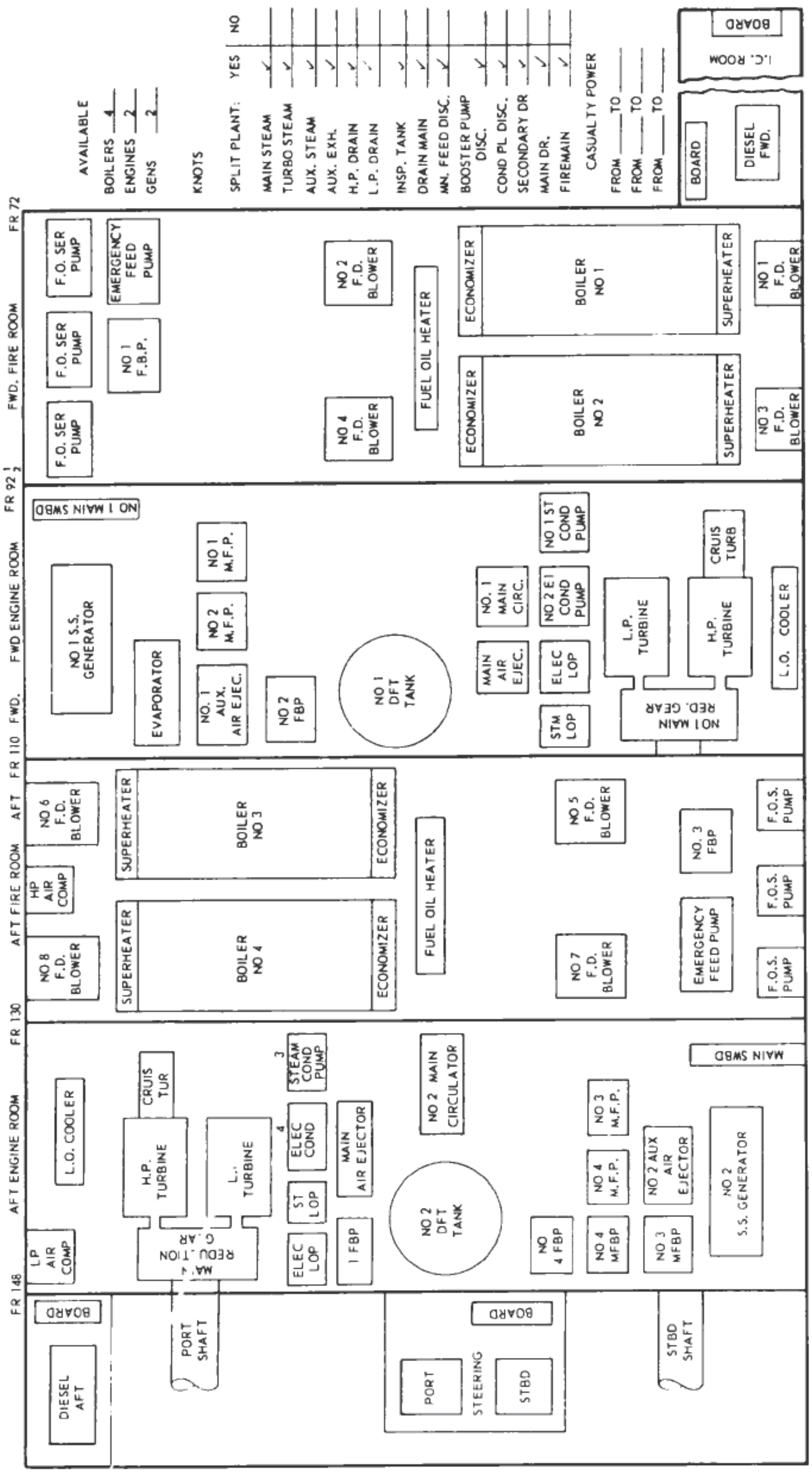

Figure 6-5.—Casualty control board.

REPAIR 5 RESPONSIBILITIES

Repair 5 is responsible for prompt and effective action in the event of major casualties in the engineering spaces and, when requested, must be prepared to aid engineering personnel in handling minor casualties. Securing and lighting off details must be designated within repair 5 with each man assigned specific duties.

Repair 5 will be asked to investigate a space whenever communications are lost or other indications show that a casualty has occurred in the space. If the space is found full of steam or severely damaged, it should be secured immediately from topside and adjacent spaces.

In the event that an engineroom must be secured, the corresponding fireroom, if possible, should steam on the auxiliary line to maintain the highest possible degree of operational readiness. Fluid in any form must not be allowed in the line entering or transiting a space in which a major casualty has occurred until the condition of the lines has been investigated and reported intact or properly isolated to main engine control, and permission has been secured to use the lines.

When entering a damaged space, investigators must ascertain the condition of auxiliary and main steam lines as soon as possible and report their findings to main engine control. A more thorough description of all damage to machinery and lines shall follow the initial findings. If damage is in the after fireroom, it is of utmost importance that the auxiliary steam lines be immediately inspected and an undamaged line from the forward engineroom to the after engineroom be isolated from any damaged section. This action is necessary so that auxiliary steam can be rapidly restored to the lube oil pumps in the after engineroom.

Communications from a damaged space to main engine control should be established as soon as possible, using the 2JV circuit. The 1JV circuit can be used in the after engineroom if the 2JV circuit is damaged. If the 1JV circuit is used, immediate steps must be taken to establish an emergency 2JV circuit to this space.

Repair 5 is responsible for rigging emergency communications circuits. Each man should be familiar with the casualty communication circuit X4OJ, and a team should be designated to rig this circuit when necessary. All men in repair 5 should also be familiar with all remote operating gear for engineering valves.

OPERATING CASUALTIES

The principal doctrine to be impressed on operating personnel in the event of a casualty to any part of the main plant is the necessity of continued operation, if possible. Try to keep the ship underway except when continued operation would damage the main engines. Notify the engineer officer of the watch as soon as possible; he, in turn will notify the officer of the deck of the casualty and of any effect on the ship's speed or the ability to answer bells. The engineer officer of the watch also notifies the engineer officer.

Before cross-connecting due to loss of steam pressure in one plant, investigate the cause of the loss of pressure. Remember that cross-connecting to a ruptured line can cause loss of pressure throughout the plant. If loss of steam pressure is due to a ruptured line or battle damage, isolate the damaged section thoroughly before cross-connecting. Ensure that lube oil pressure is maintained to the turbine at all times. In the event the auxiliary steam cannot be cross-connected, and lube oil pressure cannot be maintained either by the steam-driven or electric standby pump, the shaft must be stopped.

FIREROOM CASUALTIES

Under all circumstances, the Boilerman will notify the engineroom of the fireroom casualties.

Engineroom action that must be taken will be based on the report given by the Boilerman. When a fireroom casualty affects the operation of the engineroom, cooperation and communication between personnel of both the spaces are extremely important.

Some of the fireroom casualties that affect the engineroom, and the procedures for controlling them, are listed in the following paragraphs.

High Water

In the event of the fireroom casualty, HIGH WATER IN BOILER, with split plant operation, the Electrician's Mate should trip the ship's service generator circuit breaker and close the a-c and d-c bus-ties, the Machinist's Mate should close the main engine throttle and trip the ship's service turbogenerator. All steam line drains and all turbine drains are opened to ensure that all water is drained from the

steam lines and turbines before the cross-connection valve is opened. The plant will then be cross-connected to receive steam from another boiler. These procedures should be carried out simultaneously. The fireroom watch will close the feed check valve, secure the burners, stop the blowers, and close the main, the turbogenerator, and the auxiliary boiler steam stop valves. After the boiler is secured, the fire room watch will run down the water to the steaming level, relight fires, and bring the boiler on the line.

Low Water

The fireroom casualty, LOW WATER IN BOILER, also requires that the affected boiler be secured. It is not necessary to trip the ship's service generator as in the case of high water. Speed in cross-connecting is important, however, to maintain steam to the turbine.

Failure of Forced Draft Blower

Failure of a forced draft blower can be serious, depending on the existing conditions. If two blowers are in use and the speed of the ship is high, the ship will have to be slowed. If only one blower is in use, its failure will necessitate the securing of the boiler until another blower can be started. If there is only one boiler furnishing steam to a space, the Machinist's Mate will have to cross-connect the space and take steam from another boiler.

Loss of Fuel Oil Suction

The loss of fuel oil suction will cause the burners to sputter, fires to die out, and possible sudden racing of the fuel-oil service pump.

The fireroom watch secures all burners, leaving at least one air register on each side (superheated and saturated) open to expel any gases and to supply air for combustion of any oil that may have accumulated on the boiler floors. The forced draft blowers are kept running with approximately 2 inches of air pressure to the boiler casing.

The standby pump should be started with suction on the standby service tank. The watch notifies the engineroom of the casualty and that the fires are secured, and if unable to regain fires before steam pressure drops to the predetermined value, notifies the engineroom that the boiler is being secured by closing the main, turbo, and auxiliary boiler steam stops in the order indicated.

The fireroom watch should notify the engineroom that the boiler is secured, and open the cross-connecting valves when so directed by the engineroom. The service pump discharge pressure should be observed. If the pump races and the noise level increases, there is water in the oil and if no pressure is indicated, the pump is air bound. If there is water in the oil, the watch should run the oil to the contaminated oil tank through the recirculating line until the service line is free of water. If the pump is airbound, the priming cock is opened and the system vented.

The BT should close the air registers and slow down the forced draft blower after all oil has been burned from the furnace deck and all combustible gases expelled. After it has been determined that good oil is available, he should drop the superheat on the remaining boiler in operation to approximately 600°F and carry out the procedure for placing a boiler on the line.

He should then investigate and correct the cause of the trouble and sound the tank to determine the quantity of oil in the tank. If the oil is above the suction line, the fuel oil is contaminated or the suction line is clogged. If fuel oil contains water, he should sound the tanks in use and from which oil was transferred, and find the source of the contamination.

ENGINEROOM CASUALTIES

The operational engineroom casualties that might occur may include excessive vibration of a shaft, vibration of a turbine, loss of lube oil, and many others.

Excessive Vibration of Shaft

If a shaft develops excessive vibration, the man on watch slows the engine until the vibration ceases, and speeds up the other engine to maintain speed, as the tactical situation requires. If vibration continues at all speeds, he stops and locks the shaft, and investigates spring bearings and shaft alleys. If the cause is undetermined, he investigates the propeller, fairwaters (sleeves), and rope guards at the first opportunity.

Vibration of Turbine

If a turbine begins to vibrate, the men on watch slow down the engine and reduce the

superheat temperature. A rumbling noise probably indicates the presence of water in the casing, either from boiler priming or inadequate casing drainage.

If the turbine has been standing idle for more than 5 minutes without being spun it is probable that the rotor has been bowed temporarily. Usually, a brief slowing of the turbine will permit the rotor to straighten.

Loss of Lube Oil

It must be impressed on all personnel concerned that even a momentary loss of flow of lubricating oil will result in localized overheating and probable slight wiping of one or more bearings. Such wiping may result in only a momentary rise in the temperature of the lubricating oil discharge from the bearing(s). Damage can be prevented or minimized by stopping the shaft rotation and quickly restoring the lubricating oil flow. Continued operation with wiped bearings will cause serious derangement to the shaft packing, oil seals, and blading.

Loss of lubricating oil pressure may be caused by:

1. Failure of the system itself, including the main lubricating oil pumps.
2. Failure of steam or electrical power supply to the main lubricating oil pumps; or damage to boilers, to steam lines, or to electrical equipment.

Failure to component parts of the lube oil system may be caused by the presence of dirt, rags, or other foreign matter resulting from improper cleaning. Failure of the system may be caused by a piping failure, by a failure of the operating pump, or by failure of the standby pump to start. Standby pumps should be maintained ready to start the moment the pressure drops below the prescribed operating range. If automatic starting devices are not available on steam-driven pumps, the pumps must be lined up so that opening the throttle is the only action required to start the pumps. Steam supply lines to standby pumps should be drained continuously. Where electrical pumps are installed, personnel must be thoroughly familiar with alternate sources of power.

The general procedure for low lubricating oil pressure is as follows:

1. Upon failure of the oil pressure, immediately stop the affected shaft and simultaneously endeavor to regain lubricating oil pressure.
2. If steam pressure is available, stop the shaft by using the astern throttle. Engage the jacking gear and apply the brake. If the speed is in excess of one-half full power speed, stop the shaft by means of the astern turbine, slow down the ship to a safe speed, and then lock the shaft. Listen for, and endeavor to locate, the source of any unusual or abnormal sounds. After the affected shaft is secured, the ship's speed may be increased to the limit for locked shaft operation.
3. If steam pressure is lost in one engineroom during split-plant operation, and unless the tactical situation positively prevents, take way off the ship by backing the other engine. Determine the nature of the casualty causing the loss of steam.
   a. If a loss of steam pressure in an engineroom will not cause a loss of steam to the other plant, open the auxiliary and the main steam cross-connections immediately.
   b. If damage causes a loss of steam to the other plant, isolate the damage and then open the auxiliary and the main steam cross-connections as soon as possible.
   c. Stop and lock the affected shaft as soon as steam is available.
4. Make every effort to regain the lubricating oil pressure.

ELECTRIC PLANT CASUALTIES

Operational electric plant casualties that might occur include loss of generator, electrical fires, loss of lube oil and overloaded generator.

Loss of Generator

The proper setup for split plant operation of the electrical plant for all conditions other than battle, is with both a-c and d-c bus-tie circuit breakers (D1 and C1 fig. 6-6), OPEN on the forward switchboard, and CLOSED (D2 and C2) on the after switchboard.

If one generator loses the load when steaming split plant, trip the a-c and d-c generator circuit breakers for the affected generator, (A1 and B1 or A2 and B2). If the casualty is to the forward generator, close the bus-tie circuit breakers D1 and C1. If the casualty is to the after generator, notify the forward switchboard watch to close the bus-tie circuit breakers D1 and C1.

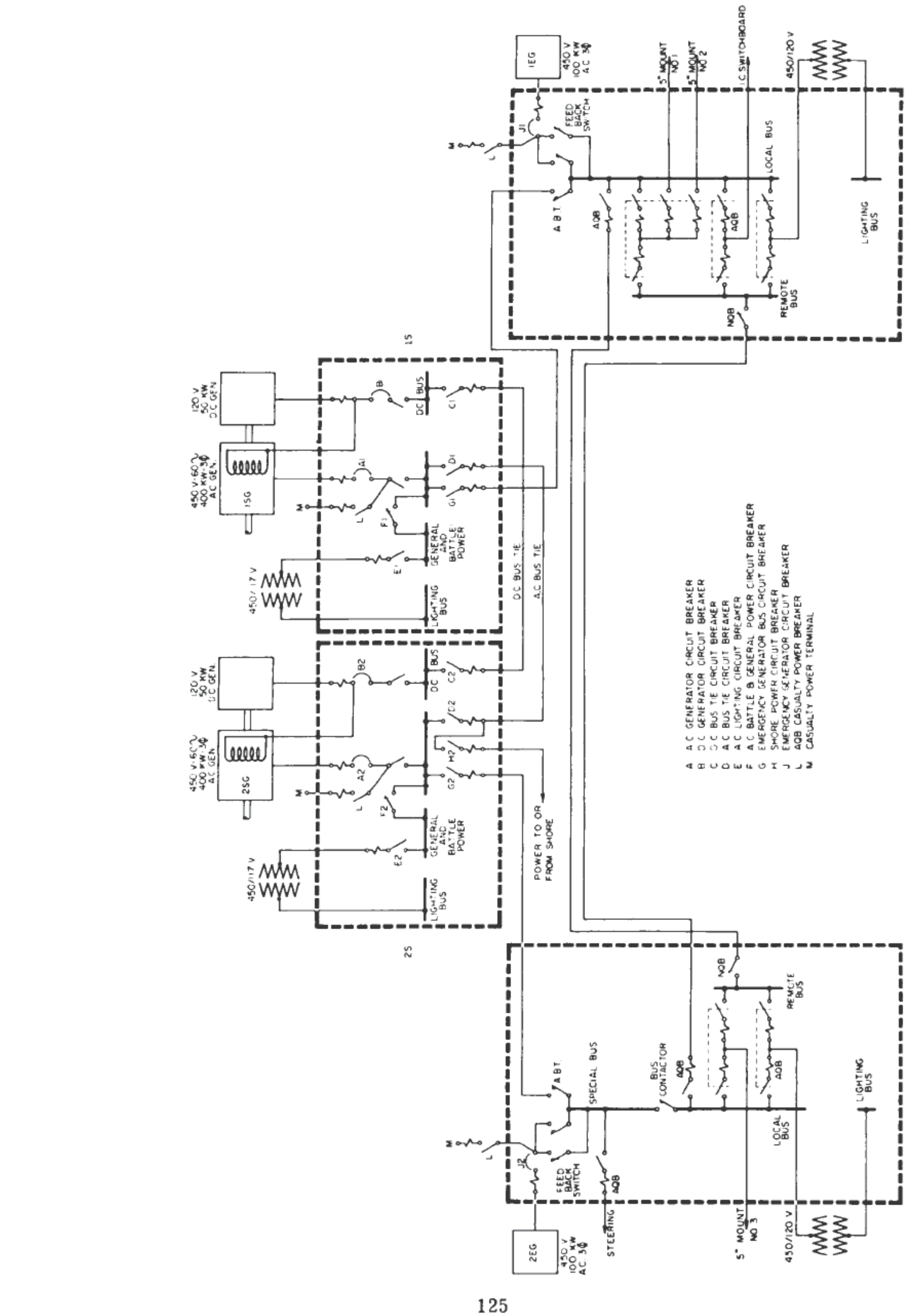

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Figure 6-6.—Ship's service and emergency switchboard interconnections.

Additional information concerning casualties to the electrical plant in a DD692 class destroyer is contained in chapter 10 of Electrician's Mate 3 and 2, NavPers 10546-A. This information includes the operation of emergency diesel generators and operation under casualty conditions.

Electrical Fires

In the event of an electrical fire the assigned Electrician's Mate deenergizes the power supply to the affected controller, power panel, or switchboard and makes certain that all power is off (normal, alternate, and emergency). Then he reports the fire to the engineer officer of the watch and the officer of the deck, uses a CO2 fire extinguisher, and secures all ventilation. He should not stand directly in front of the panel that is on fire. He should keep low and to one side and set a reflash watch until the danger of a reflash has passed. The electrician should open the panel with rubber gloves, using a rubber mat or boots, to determine and repair the source of trouble.

If an electrical fire should occur in a switchboard with a generator on the line, trip the a-c and d-c generator circuit breakers. The Machinist's Mate trips the overspeed trip on the generator and notifies the control engineroom, which in turn notifies the officer of the deck and the engineer officer.

The Electrician's Mate secures the voltage regulator, trips the a-c and d-c bus-tie circuit breakers, and opens the feedback circuit breaker. If the fire is in the forward switchboard he notifies the after switchboard watch to open the after a-c and d-c bus-tie circuit breakers. He uses a CO2 fire extinguisher on the fire. The damaged section of the switchboard must not be reenergized until repairs have been made.

If an electrical fire occurs in a generator, the generator must be secured immediately. If the fire occurs while operating split plant, the Electrician's Mate trips the a-c and d-c generator circuit breakers for the affected generator, closes the a-c and d-c bus-ties, and uses a CO2 fire extinguisher on the fire. If a generator fire should occur while operating with a single generator, the switchboard must be stripped of all non-vital circuits and the vital circuits supplied from the emergency diesel generator.

Loss of Lube Oil

Upon failure of generator lube oil pressure, the electrical load must be removed from the affected generator, and the generator stopped immediately. The normal procedure is to trip the generator circuit breaker, close the a-c and d-c bus ties, and close the generator turbine throttle valve. The hand-operated lube oil pump must be used to maintain lube oil pressure to the bearings until the turbine is completely stopped. After the turbine has stopped, investigate and correct the casualty.

Overloaded Generator

Overload on a generator, is reduced by removing non-vital loads. Power should not be interrupted to vital machinery and circuits unless absolutely necessary. Vital machinery and circuits include the steering gear, IC switchboard, fire pumps, drainage pumps, vital auxiliaries in the boiler and engine rooms, gun mounts, and navigational lights.

Maximum Operating Limits

Knowing the maximum operating limits of the electric plant is of prime importance during casualty operation. You must know the maximum allowable bearing temperatures, generator winding temperatures, maximum generator loads, etc.

Supplying vital power during casualty operation, may require that generators be operated under overloaded conditions. Assuming that the prime mover can handle the overload, the temperature of the generator windings is the determining factor during sustained overloads. A portable blower may be used on open type machines to keep the winding temperature within safe limits.

ELECTRIC DRIVE CASUALTIES

The control of operational casualties to an electric drive system requires procedures that differ, depending upon whether the system is a turboelectric a-c drive or a diesel-electric d-c drive. These two systems are discussed in chapter 14 of Electrician's Mate 3 & 2, NavPers 10546-A.

TURBOELECTRIC A-C DRIVE

Operational casualties in this type drive may include (1) protective relays operate, (2) automatic field excitation control fails, (3) propulsion generator casualty, (4) propulsion motor casualty, and (5) loss of lube oil.

Protective Relays

If a protective relay operates and trips open the propulsion field circuits, place the turbine governor lever in the MANEUVERING-SPEED position, return the field lever to the OFF position, return the reverser lever to the OFF position, remove the excitation and control power, and shut down the turbine generator by tripping the throttle valve.

If the setup levers were in the TWO-MOTOR position at the time the relay operated, the setup levers should be returned to the ONE-MOTOR position. Remove the generator neutral ground connection by disconnecting the ground current limit resistor. With all circuits deenergized use an insulation-resistance tester to locate the ground or fault. If the motors were operating in parallel at the time the relay operated, the fault may be in either motor circuit.

Failure of Automatic Field Excitation Control

Loss of field excitation requires shifting to manual control by turning the standby excitation control switch on the control panel to the MANUAL position. This action cuts the regulator out of the circuit so that the excitation can be controlled by means of the exciter field rheostat.

To prevent overloading the propulsion equipment when under manual control, do not exceed the generator field current values specified for the various speeds on the field current vs. RPM nameplate. The specified values of field current are maximum for safe continuous operation.

The change from automatic to manual control of excitation or vice versa can be made at any time. Before changing from automatic to manual, the exciter field rheostat should be turned to the position that gives maximum generator field current. Immediately after the control is switched to manual, adjust the generator field current to the proper value corresponding to the propeller rpm indicated on the nameplate.

Propulsion Generator Casualty

A propulsion generator casualty requires shifting to two-motor operation. To shift to two-motor operation, the reverser levers in both engine rooms are placed in the STOP position. The motor setup levers in both engine rooms are then placed in the TWO-MOTOR position paralleling the motors, and control is exercised in the active generator engine room. Either motor setup lever may be returned to the ONE-MOTOR position in an emergency. About 70 percent of full speed is obtainable in two-motor operation without overloading the active propulsion generator.

Propulsion Motor Casualty

A casualty to a main propulsion motor requires prompt action in shutting down the motor. If the casualty occurs during two-motor operation, the motor setup lever for the affected motor is thrown to the single motor position, and the casualty investigated. If a protective relay has operated to remove the motor field, proceed as described previously.

Loss of Lube Oil

Upon loss of lube oil, the main propulsion generator turbine must be stopped immediately. To bring the turbine and generator to rest in a minimum amount of time, first trip the generator by pulling the turbine trip handle, then energize the main propulsion motor momentarily with the field lever in its first position. With the generator loaded by the motor starting current, while the turbine's steam valve is tripped closed, the generator rotor and turbine will quickly come to rest.

DIESEL ELECTRIC D-C DRIVE (FLEET TUG)

Operational casualties that may occur to this type of drive may include casualties to any one of the four main propulsion generators or exciters, the main propulsion motor, and the control equipment and associated circuits.

Propulsion Generator Casualty

A casualty to one of the main propulsion generators or associated exciter, requires cutting the effected generator out of the series propulsion loop.

It is not necessary to turn the speed controller to the STOP position when cutting a generator into or out of the propulsion circuit. Normally the controller should be brought to a position not higher than the 11th (engine operating at 350 RPM). When required, a generator may be cut out of the circuit while the engine speed is in excess of this as the generator set-up switches are designed for such service. Wait several seconds between the opening of the generator's control switch and its set-up switch. This reduces arcing at the set-up switch contacts, and prevents flashover of the generator commutator.

Propulsion Motor Casualty

The main propulsion motor is actually two identical motors mounted on a common shaft. If a casualty occurs to one of the armatures it may be bridged with disconnect links to remove it from the propulsion loop as described in Electrician's Mate 3 & 2, NavPers 10546-A. When one armature is bridged, the capacity of the motor is reduced by 50 percent, and not more than two propulsion generators should be connected in the propulsion loop.

HOT BEARINGS.—If a motor bearing overheats, remove the load but keep the motor turning slowly to keep the bearing from "freezing." Cool wet rags may be placed around the bearing housing to bring the bearing temperature to a safe value.

Control Console Casualty

A casualty to the pilothouse control console or associated circuitry requires shifting control of the engines to the engineroom station. To shift control to the engineroom, place the controllers at both control stations on the STOP position, turn the excitation control switch to OFF, then turn the engineroom-pilothouse control transfer switch to the ENGINEROOM position. The control transfer switch and the excitation control switch are interlocked so that the excitation control switch must be in the OFF position before the control transfer switch can be operated. Then turn the excitation control switch to ON.

BATTLE CASUALTIES

Shell or torpedo hits in engineering spaces usually result in multiple casualties to machinery and systems. The corrective action for any particular casualty depends on the location and extent of damage. While battle casualties differ in many respects, the following procedures apply to any casualty of this type.

1. Secure the space or isolate damaged sections, as practical.
2. Cross-connect systems or plants when possible.
3. Stop and lock the shaft in the event of serious damage to the turbine, reduction gear, the main shaft, or in the event of loss of lubricating oil pressure to the main engines.
4. Carry out applicable casualty control procedures in the event of damage to machinery or piping systems.
5. Take all precautions to prevent flooding of the space. Put all available pumps on the bilges of the damaged space; plug all holes and (if possible) prevent flooding of other spaces.
6. Use soft patches, blank flanges, wooden plugs, or other suitable means to repair lube oil lines, fresh water lines, salt water cooling mains, auxiliary exhaust lines, and other low pressure lines.
7. If a ruptured steam line line prevents entry of repair party personnel into a space, secure the space by using remote controls.
8. Extinguish fires and investigate damage as soon as possible.
9. Make repairs to return machinery or the space back to service, if possible.
10. Keep communication lines open and keep main engine control advised of the existing conditions.

ELECTRICAL CASUALTIES

Battle damage to a ship is almost certain to include damaged electrical equipment, and severed power, and lighting cables.

Damaged Cable and Equipment

In any casualty involving damage to electrical cable and equipment, electrical circuits may be a hazard if they remain energized. The individual circumstances surrounding each case of damage will dictate the action to be taken. In cases of serious damage it is usually necessary to remove electrical power from all cables in the damaged area to prevent the ignition of combustible liquids and gases. Continued operations, however, may require the reestablishment of power to undamaged circuits, including those that extend through the damaged area.

Splices may be made or temporary jumpers run in some cases to reestablish power to the required circuits. Lighting circuits are not to be disregarded in this connection, as damage control activities can be seriously handicapped or rendered impossible by inadequate lighting at the scene of damage.

Damaged electrical equipment must be isolated from all available sources of power. In case of a damaged switchboard, all circuits feeding to the switchboard from remote sources must be deenergized and tagged at the source.

Casualty Power System

The casualty power system in a DD692 destroyer is described in chapter 10 of Electrician's Mate 3 and 2, NavPers 10546-A. The system is limited to the bare minimum of electrical facilities, which are required in the event of damage to keep the ship afloat and to get it out of a danger area. The important features of the basic design of the casualty power system include the preservation of the watertight integrity of the ship, simplicity of installation and operation, flexibility of application, interchangeability of parts and equipment, minimum of weight and space requirements, and the ability to accomplish the desired functions.

The casualty power system is a temporary means of providing power and is not a means of making temporary repairs. The system is purposely limited in its scope in order to retain its effectiveness. The more equipment that is added and the more the system is expanded, the greater would be the possibility of error in making connections and the possibility that faults at relatively unimportant equipment will cause loss of power at vital equipment. It is also probable that the casualty power system, if expanded, would be burdened with miscellaneous loads at a time when its use would be essential for vital loads.

The electrical casualty power system in a DD692 class destroyer is illustrated by the schematic diagram in figure 6-7. The system contains no permanently installed cables, except for the vertical risers and bulkhead terminals. The risers are installed for carrying circuits through decks without impairing the watertight integrity of the ship. A riser consists of a TSGA-60 cable extending from one deck to another with a riser terminal connected to each end for attachment of portable cables.

The portable cables are THOF-42 cables in suitable lengths provided for forming all circuits that are required for supplying power to equipment designated to receive casualty power. While the normal current carrying capacity of THOF-42 cables is 43 amperes, its casualty rating is 200 amperes. Under normal conditions this cable will carry 200 amperes for four hours without damage to the cable.

The bulkhead terminals are provided for carrying circuits through bulkheads without impairing the watertight integrity of the ship.

The power panels supplying equipment designated for casualty power service are equipped with terminals so that casualty power can be fed into the panels. These panels can also be used as a source of power for the casualty power system in the event that power is still available from the permanent feeders to the panels. However, the decision to take power from the panel instead of the switchboard must be based on knowledge that equipment on that panel will not be required for the safety of the ship. Operating the equipment normally supplied by the panel and the equipment to be supplied with casualty power may cause an overload on the circuit breaker supplying the panel. Portable switches are located in several strategic positions throughout the ship for use with the casualty power system.

In general, the casualty power system provides a horizontal run of portable cable along the main deck with risers for the power supply and loads extending to and from this level. Rigging and unrigging casualty power cables are described in chapter 10 of Electrician's Mate 3 and 2, NavPers 10546-A.

The ship's service switchboards, 1S and 2S, and the emergency switchboards, 1E and 2E, are provided with a casualty power riser terminal, M, installed on the back of the switchboard (fig. 6-6). Each casualty power riser terminal is connected to the buses through a standard 250-ampere AQB circuit breaker. The circuit breakers have an instantaneous (magnetic) trip element setting to prevent tripping of the generator breaker or fusing of the casualty power cable under short-circuit conditions. Connections to the buses are between the generator circuit breaker and disconnect switch.

CASUALTY CONTROL TRAINING

Knowledge is the keystone of casualty control. Maximum knowledge of the operating details of the engineering installation must be

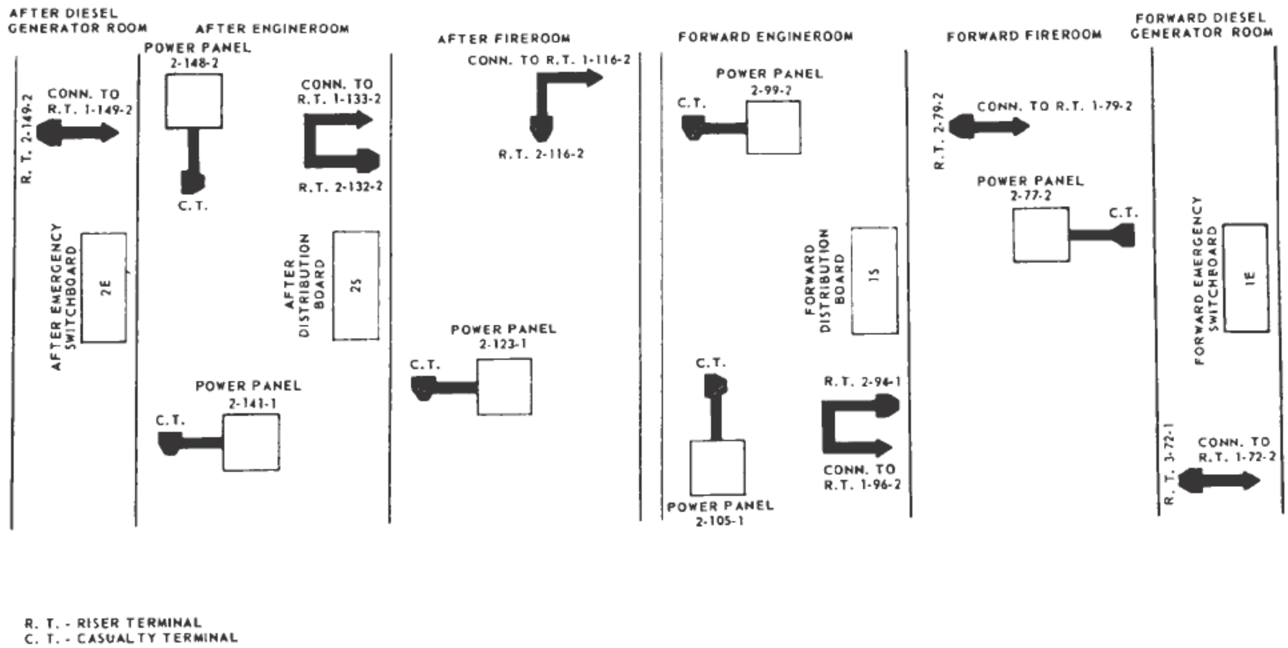

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Figure 6-7.—Electrical casualty power system.

imparted to the greatest possible extent to all engineering personnel. Instruction in casualty procedures must be based on thorough instruction in the proper and normal operating procedures of the plant. Complete familiarity with normal operation must be gained by all personnel concerned before any attempt is made to carry out simulated casualties.

Casualty control training must be a continuous step-by-step procedure with constant refresher drills. These drills comprise on station training with frequent instruction and inspection of watch sections by engineering officers and leading petty officers to ensure that the men are indoctrinated in the proper procedures and are familiar with the installations in their machinery space. Instructions pertaining to the machinery setup for various engineering conditions of readiness must be well promulgated and inspections made to ensure that these instructions are carried out.

Realistic simulation of casualties must be preceded by adequate preparation. The amount of advance preparation necessary is not always readily apparent unless care is exercised to visualize fully the consequences of error, which may be made in the handling of simulated casualties intended to be of a relatively minor nature. Hence, the simulation of major casualties and battle damage must be preceded by an extremely complete analysis and by careful instruction to all participants.

Any new crew must be given an adequate opportunity to become familiar with the ship's systems and equipment prior to simulating any casualty that may have other than purely local effects. In the preliminary phases a so-called DRY RUN is a useful method for imparting early knowledge of casualty control procedures without endangering the ship's equipment.

Under this procedure, a casualty is announced and all individuals are required to report as though action were taken, except to indicate that action was only simulated. Definite corrective actions can be made, and with careful supervision, the timing of individual actions can be made very realistic. Such DRY RUNS should always be carried out before actually attempting to simulate realistically any involved casualty, regardless of the state of training.

Individual casualty procedures should be the basis of casualty control training with emphasis

on operating casualties in the early stages. Conducting battle problems before a crew is proficient in handling operating casualties only results in confusion and disrupts the efforts to organize and coordinate the teams. A battle problem is a sequence of individual casualties that require individual casualty control procedures by the teams, and intraplant coordination between teams. With well organized training in individual casualties and with good communications, a crew can proficiently handle any battle problem.

CONDUCTING AND SUPERVISING ELECTRICAL CASUALTY DRILLS

As an EM1, or Chief Electrician's Mate, you will be required to conduct and supervise electrical casualty drills. This will include conducting such drills as fires in generators, switchboards, and other electrical equipment, emergency securing of generators, use of emergency generators, stripping switchboards of nonvital circuits, supplying casualty power to vital machinery, and others.

In addition to conducting frequent DRY RUNS, you must ensure that all Electrician's Mates get some experience in actually performing the casualty operations. The men stationed on the switchboard during general quarters will get electric plant casualty operating experience during general quarters drills. You must ensure that the other switchboard watchstanders get this experience. Always obtain permission from appropriate authority however, before conducting any casualty drills that may affect the status of the engineering plant.

CHAPTER 7

MAINTENANCE AND REPAIR PROCEDURES

This chapter discusses shipboard electrical maintenance and repair procedures. Repairs, alterations, and the types of availabilities are defined. The Standard Navy Maintenance Management System and its application to the maintenance of electrical equipment is discussed.

The chapter also includes material concerning the preparation of work requests and failure reports.

PLANNED MAINTENANCE SYSTEM

A Standard Navy Maintenance and Material Management System, of which the Planned Maintenance System is a part, is now being installed throughout the operating fleet.

SCOPE AND PURPOSE OF THE SYSTEM

The Planned Maintenance System is designed to prescribe minimum maintenance requirements for all shipboard equipment and to simplify procedures for easy management. It is also designed to define the preventive shipboard maintenance required, schedule its performance, define safety precautions involved, and list the methods and tools to be used. The result is reduced casualties on operating equipment and increased equipment readiness.

The Planned Maintenance System, as installed aboard ship, consists of Planned Maintenance System Manuals, Cycle Schedules, Long Range or Quarterly Schedules, Weekly Schedules, and Maintenance Requirement Cards.

The Planned Maintenance System Manual

The Planned Maintenance System Manual is prepared for each department and contains an index of the minimum preventive maintenance requirements for each component installed. The engineering department manual is normally kept in the log room and is primarily used by the engineer officer and his assistants for planning and scheduling maintenance. A table of contents for each group is the department and a page for each component or equipment involved (fig. 7-1), are basically what the manual consists of. A short description is given of all maintenance requirements pertinent to the component, the frequency with which the maintenance actions will occur and the rate and time required to accomplish the required maintenance.

The frequency code is as follows:

D-Daily	A-Annually
W-Weekly	C-Overhaul Cycle
M-Monthly	R-Situation Requirement
Q-Quarterly	i.e. 100 hours, prior to
S-Semiannually	getting underway, etc.

The Cycle Schedule

The Cycle Schedule (fig. 7-2), is a visual display of preventive maintenance requirements based on an overhaul cycle. This schedule is prepared by the Type Commander for each maintenance group. All PM items are within the capability of onboard personnel.

The components for each maintenance group are listed in the cycle schedule. The semiannual, annual, and overhaul cycle requirements are scheduled into "Quarters after Overhaul". Each requirement should be performed by the ship in the quarter scheduled.

Also included in the cycle schedule are the quarterly and monthly requirements that must be performed each quarter.

The Long Range or Quarterly Schedule

The Long Range or Quarterly Schedule (fig. 7-3) is a visual display consisting of two identical quarterly schedule forms, one for the current

System, Subsystem, or Component	Reference Publications and/or Maintenance Significant Number
Distribution Switchboards and Associated Voltage Regulators	

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd	Man Hours	Related Maintenance
					BATTERY CHARGING SWITCHBOARD				
EB	ZZ6GPA9	34	0923	A	1. Clean and inspect the switchboard and switchboard equipment.	A-1	EM3 EMFA	1.5 1.5	None
					EMERGENCY GENERATOR SWITCHBOARD				
EB	ZZ1GSW4	34	2294	A	1. Clean and inspect the switchboard and switchboard equipment.	A-2	EM2 EMFN EMFN	2.0 2.0 2.0	None
					MAIN DISTRIBUTION SWITCHBOARD				
EB	ZZ1GSWJ	34	2295	A	1. Clean and inspect the switchboard and switchboard equipment.	A-3	EM2 EMFN EMFN	2.0 2.0 2.0	None
EB	ZZ1GTG6	53	0926	C	1. Check switchboard and electrical measuring instruments three (3) months prior to entering shipyard. Deliver all defective meters to tender or shipyard during or prior to shipyard overhaul for repairs.	C-1	EM1 EM2	1.0 1.0	None
CT	ZZ1GTGO	A3	0927	C	1. Send all portable test instruments to an authorized standards laboratory for calibration.	C-2	EM1	1.5	None

Bureau Page Control No. $\frac{\text{EL-5}}{10}$

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Figure 7-1.—Sample page from Planned Maintenance System Manual.

EQUIP. PAGE	CYCLE SCHEDULE ______ / MAINT. GROUP ______ / COMPONENT	SCHEDULE AS INDICATED / QUARTER AFTER OVERHAUL 1 5 9	2 6 10	3 7 11	4 8 12	EACH QUARTER
EL-1	Portable Storage Batteries					Q-1
EL-2	Portable Tools & Installed Receptacles	A-1				M-1
EL-3	Controllers		A-1 18M-6		C-1 (12) 18M(12)	R-1 M-1 Q-1
EL-4	Motors	A-1	18M (6)	C-1 (11)	18M(12)	M-1 Q-1 Q-2
EL-5	Battery Charging Switchboard			A-1		
EL-5	Emer. Gen. Swbd.	A-2				
EL-5	Main Dist. Swbd.		A-3	C-1(11)	C-2(12)	
EL-6	Degaussing			A-1		R-1
EL-7	S/S Gen # 1	S-1		S-1		R-1 M-1
EL-7	S/S Gen # 2		S-1		S-1	R-1 M-1
EL-8	Emer. Gen # 1	S-2	S-1	S-2	S-1	M-1
EL-8	Emer. Gen # 2	S-1	S-2	S-1	S-2	M-1
EL-10	Auto. Bus. Trans.		S-1		S-1	
EL-11	M/G Sets					Q-1

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Figure 7-2.—Cycle schedule.

MAINT. GROUP ELECTRICAL YEAR 1964 QUARTER AFTER OVERHAUL NO. 2

MONTH APRIL MONTH MAY MONTH JUNE

EMPLOYMENT SCHEDULE

	9	17 24		30		14	20	31			15	
ASW	TENDER	ISE	UPKEEP		ASW	UPKEEP	OPS		TENDER	AVAIL.	ASW	
Q-1												
M-1					M-1					M-1		
	A-1 M-1				M-1				Q-1 M-1			
	Q-1		M-1			M-1			Q-2	M-1		
			A3									
	M-1		M-1			M-1			M-1			
			M-1 S-1			M-1			M-1			
	M-1 S-1				M-1				M-1			
			S-2 M-1			M-1					M-1	
	S-1											
				Q-1								

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Figure 7-3.—Long range or quarterly schedule.

quarter, and one for the subsequent quarter. The cycle schedule and both quarterly schedules are contained in the same visual display holder known as the "Maintenance Control Board" which is usually located outside the log room. Maintenance requirements are scheduled by the engineer officer on these schedules. The maintenance requirements to be scheduled are determined from the cycle schedule.

Each Quarterly Schedule form contains blanks in which to insert the current year and month, the ship's employment schedule, the quarter after overhaul involved, and the maintenance group concerned. It contains thirteen columns, one for each week in the quarter, to facilitate scheduling. Maintenance requirements are transcribed from the appropriate Quarters After Overhaul column of the cycle schedule to the specific week of the current quarterly schedule in which the work is expected to be done. This schedule is flexible, and work can be easily rescheduled to accommodate employment schedule changes which may occur. The cycle and quarterly schedule combined will give the overall planned or preventive maintenance program for the ship.

The Weekly Schedule

The Weekly Schedule (fig. 7-4) is another visual display which is posted in each maintenance group's working area along with a copy of the applicable portion of the Planned Maintenance System Manual. It assigns specific personnel to perform specific maintenance tasks on specific components on a specific date. The weekly schedule contains a list of components involved in the maintenance group area and is used by the working area supervisor to assign work and record its completion.

The Maintenance Requirement Card

The Maintenance Requirement Card (fig. 7-5), is a 5- by 8-inch card defining preventive maintenance tasks in sufficient detail to enable assigned personnel to perform the task without difficulty. It lists the rate, time, tools, parts, and materials required to perform the maintenance tasks as well as detailed procedures and safety precautions. A complete working set of applicable maintenance requirement cards with a container is installed in each maintenance group working area where they will be readily accessible to those performing the maintenance tasks. A master deck of all Maintenance Requirement Cards for the engineering department is kept in the log room along with the Planned Maintenance System Manual.

Typical Maintenance Action

The operation of the system can best be shown by describing a typical maintenance action. The Main Distribution Switchboard will be used in this example.

ELECTRICAL WORK SCHEDULE FOR WEEK OF APRIL 21 - 27

COMPONENT	MAINTENANCE RESPONSIBILITY	PAGE	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT SUN	OUTSTANDING REPAIRS AND P.M. CHECKS DUE IN NEXT 4 WEEKS
Portable Storage Batteries	SMITH, EM FN	EL-1	W-1						
Portable Tools	SMITH, EM FN	EL-2			W-1				
Controllers	EDWARDS, EM-2	EL-3							
Motors	KLINE, EM-3	EL-4	M-1						
Battery Charging Switchboard	KLINE, EM-3	EL-5							
Emer. Gen. Swbd.	JONES, EM-2	EL-5							
Main Dist. Swbd.	JONES, EM-2	EL-5		A-3					
Degaussing	EDWARDS, EM-2	EL-6	W-1		D-1				
No. 1 Ship's Service Generator	DWYER, EM-1	EL-7	D-1 W-1	D-1	D-1	D-1 M-1	D-1	D-1	
No. 2 Ship's Service Generator	DWYER, EM-1	EL-7	D-1 W-1	D-1	D-1 M-1	D-1	D-1 S-1	D-1	
Emer. Gen #1	CARR, EM-3	EL-8	D-1	D-1	D-1	D-1	D-1	D-1	
Emer. Gen #2	CARR, EM-3	EL-8	D-1 S-2	D-1	D-1 M-1	D-1	D-1	D-1	
Auto. Bus. Trans	EDWARDS, EM-2	EL-10							
M. G. Sets	KLINE, EM-3	EL-11							

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Figure 7-4.—Weekly schedule.

The engineer officer establishes the quarterly maintenance schedule from the cycle schedule. The schedule being established is for the second quarter after overhaul—April, May, June.

Under the equipment page column of the Cycle Schedule (fig. 7-2), it is noted that annual maintenance (A-3) is required on the Main Distribution Switchboard. To determine whether or not the maintenance can be accomplished underway the engineer officer refers to the Planned Maintenance Manual, page EL-5 (fig. 7-1), and schedules it accordingly. The extent of the maintenance required, the necessity of securing equipment vital to the underway operation of the ship, as well as many other factors are taken into consideration in scheduling underway maintenance.

In the quarterly schedule (fig. 7-3), the annual maintenance requirement is scheduled for the fourth week in April during an upkeep period when the ship is not underway. The rest of the schedule is made up in the same way.

As a leading Chief or First Class your job is now to review the engineer officer's quarterly schedule and establish a weekly schedule for the 4th week in April, the week in which maintenance action is to be taken on the switchboard.

The weekly and daily maintenance requirements have been pre-printed on the Weekly Schedule (fig. 7-4), since they are repetitively routine. This leaves only the monthly and less frequent maintenance requirements to be scheduled. In this case the maintenance requirement is scheduled for Tuesday, 22 April.

Preventive maintenance action which has not been accomplished due to a change in operating schedule, workload, or any other reason is to be rescheduled for a future date. The subsequent quarterly schedule is designed for this purpose, allowing a continuity in fulfilling all maintenance requirements. The petty officer in charge will make the changes on the quarterly schedule as well as check off the maintenance that has been completed.

After noting the weekly schedule, the man assigned to accomplish the work will obtain the necessary Maintenance Requirement Card, (fig. 7-5), and proceed from there. The procedure, tools required, estimated time it will take, plus other pertinent information, is found on this card.

The success of this system depends greatly on you as a Chief or First Class Petty Officer in charge. The planned maintenance system cannot guarantee that failures will not occur. If properly used, however, it will reduce them.

REPAIRS AND ALTERATIONS

Ships are self-sustaining with respect to normal repairs that are within the capacity of the ship's force, but, they cannot operate for indefinite periods without major repairs. Therefore, specific intervals of time must be allotted for repairs and alterations at repair activities afloat and ashore.

Repair activities afloat consist of repair ships and tenders whereas repair activities ashore consist of naval shipyards, repair facilities, and commercial shipyards under contract with the Navy. This chapter discusses repair, alterations, and maintenance procedures of naval ships by the forces afloat and by shore-based repair activities.

Maintenance work can be grouped into the general categories of (1) repairs, (2) alterations, and (3) alterations equivalent to repairs.

REPAIRS

A repair as defined in Navy Regulations is "work necessary to restore a ship or article to serviceable conditions without change in design, materials, number, location, or relationship of the component parts."

ALTERATIONS

An alteration as defined in Navy Regulations is "any change in the hull, machinery, equipment, or fittings which involves a change in design, materials, number, location, or relationship of the component parts of an assembly regardless of whether it is undertaken separately from, or incidental to, or in conjunction with, repairs." Alterations are classified as navalts and shipalts.

NAVALTS

A NAVALT is an alteration that affects the military characteristics of a naval vessel. NAVALTS are identified by the word NAVALT, and a number, if any, assigned to the project in the Ship Improvement Guide. (The issuance of a Ship Improvement Guide project card, or a class Improvement Plan which describes the alteration, indicates that the alteration has been approved or is under active consideration.) The document that describes the alteration in detail and lists the specific vessels to which it is applicable is also known as a NAVALT.

SYSTEM	COMPONENT	M.R. NUMBER	
Electric Plant	Main Distribution Switchboard MAINT. SIGNIFICANT NO.	EL-5 A-3	
SUB-SYSTEM	**RELATED M.R.**	**RATES**	**M/H**
Power Distribution Switchboards	None	EM2 EMFN EMFN	2.0 2.0 2.0

M.R DESCRIPTION

1. Clean and inspect the switchboard and switchboard equipment.

TOTAL M/H: 6.0

ELAPSED TIME: 2.0

SAFETY PRECAUTIONS

1. Secure bus tie feed back at emergency switchboard.
2. Secure ship service and degaussing generators. Shut throttle valves, wire shut, and tag, "Out Of Service".

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Vacuum cleaner
2. Clean dry rags
3. Flashlights
4. Rubber gloves 5000/7000 volt
5. Socket sets 1/4", 1/2"
6. 8" adjustable wrench
7. Air drying varnish
8. Extension light
9. Voltage tester

(cont. on Page 2)

PROCEDURE

Preliminary:

a. Obtain permission from engineer officer to secure the switchboard for cleaning and inspection, (preferably; this preventive maintenance should be performed in port at night). Rig temporary lights and ventilation if necessary.

b. Open generator switches, and degaussing switch on front of switchboard. Secure bus tie feed back at emergency switchboard. Tag, "Out Of Service".

c. Notify authorized personnel to secure ship service and degaussing generators, if in service. Shut throttle valves, wire shut, and tag, "Out Of Service".

d. Open door to rear of switchboard and place safety tag at the entrance to rear of switchboard. Make tools available at the switchboard.

1. Clean and Inspect the Switchboard and Switchboard Equipment.

   a. Wear 5000/7000 volt rubber gloves and have safety

(cont. on Page 2)

LOCATION

Page 1 of 2 | EB | ZZ1G | SWJ | 34 | 2295 | A

92.100

Figure 7-5A.—Maintenance requirement card, front.

Tools, Parts, Materials, Test Equipment (cont.)

10. 6",8" screwdriver
11. Safety tags
12. 1" paint brush
13. Wire
14. 3/8-7/16, 1/2-9/16 wrenches
15. Fine file

Procedure (cont.)

man standing by. Test all bus bars and switches, with voltage tester, to ensure all power is secured.

b. Vacuum all bus bars, bus bar supports, terminals, control mechanisms, switches, circuit breakers, etc., to remove dust and dirt.
c. Wipe all components, bus bars, and cable trees with clean dry rags.
d. Inspect and tighten all electrical and mechanical connections. Use locking devices such as jam nuts or lock washers, where necessary, to keep connections tight.
e. Inspect the supports of bus bars and make sure that the supports will prevent the striking of bus bars of different polarities, or the striking of grounded part during periods of shock.
f. Inspect coils, transformers, and cables, for insulation breakdown such as chips, cracks, or flaking, and touch up with air drying varnish.
g. Remove arc chutes on circuit breakers and inspect stationary and movable contacts for burrs, pits, and burned spots. Dress with fine file, as necessary.
h. Inspect switchboard for any loose items that may have been left inside.
i. After thorough inspection and removal of all loose gear, close door to rear of switchboard, remove tags, and wire.
j. Notify authorized personnel to start ship service generator, degaussing generator. If required, energize switchboard, and notify engineer officer and officer of the deck the switchboard is back in service.

Page 2 of 2	EB	ZZ1G	SWJ	34	2295	A

92.100

Figure 7-5B.—Maintenance requirement card, back.

SHIPALTS

A SHIPALT is an alteration under the technical cognizance of the Bureau of Ships, regardless of whether or not it affects the military characteristics of a vessel. Thus, some alterations may be both NAVALTS and SHIPALTS whereas others may be only SHIPALTS. The document that describes an alteration and lists the specific vessels to which it is applicable is known as a SHIPALT.

Each SHIPALT is identified by a composite number consisting of two serial numbers and the letter "A", "K", "F", or "D". Serial numbers are assigned chronologically in the order in which alterations are approved. The first serial number is the TYPE SERIAL NUMBER; the number of the alteration within a type (CL or CA). The second serial number is the SHIP SERIAL NUMBER; the number of the alteration for a specific ship within the type. The letter indicates the expenditure account chargeable.

For example, consider SHIPALT CVE 621A72-SIBONEY. CVE is the ship type designation (in this case an escort carrier); 621 indicates that this is the 621st alteration approved for CVEs; "A" designates the account to which the charges will be made; 72 indicates that this is the 72nd alteration approved for the USS SIBONEY.

Priority of Alterations

The priority of an alteration expresses its relative importance with respect to other alterations. Alterations affecting military characteristics of naval vessels are classified according to priority by the Chief of Naval Operations for a given fiscal year.

Alterations NOT affecting the military characteristics of naval vessels are classified according to priority by the Chief of the Bureau of Ships as follows:

Class A—Mandatory
Class B—Essential
Class C—Desirable

Relative priorities of individual alterations for installation planning are established from annual reviews by the Office of the Chief of Naval Operations and the Bureau of Ships, and promulgated in the Material Improvement Plan (MIP) and Operational Improvement Plan (OIP).

ALTERATIONS EQUIVALENT TO REPAIRS

An alteration shall be considered equivalent to a repair when such alteration consists of:

1. The use of different materials that have been approved for like or similar use and such materials are available from standard stock.
2. The replacement of wornout or damaged parts, assemblies or equipment, requiring renewal by those of later and more efficient design previously approved by the bureau concerned.
3. The strengthening of parts that require repair or replacement in order to improve the reliability of the parts and of the unit, provided no other change in design is involved.
4. Minor modifications involving no significant changes in design or functioning of equipment but considered essential to prevent recurrence of unsatisfactory conditions.

Only the bureau exercising technical control over the article, or the authority to whom such technical control has been delegated by that bureau shall designate an alteration as being equivalent to a repair and approve it for accomplishment.

Ship Improvement Guide

The Ship Improvement Guide is a compilation of those alterations and improvement projects affecting the military characteristics of ships and approved by the Chief of Naval Operations. It is the administrative document by which the Chief of Naval Operations establishes the nature and extent of improvements in existing ships to meet operational requirements. It is also the basis for installation and procurement planning to effect these improvements. The Ship Improvement Guide comprises Part I, Class Improvement Plans, and Part II, Ship Improvement Guide Project Cards.

The Class Improvement Plans consist of summaries of those uncompleted projects and new improvement items affecting military characteristics and applicable to particular classes of vessels. These plans are feasible of accomplishment and provide the greatest increase in military effectiveness of the ship within the limitations of weight, space, moment, and habitability.

The Ship Improvement Guide Project Cards contain detailed information on each of the various projects summarized in the Class Improvement Plans. Each project card is assigned

a serial number and also includes the project title, cognizant bureau, brief description of the project, present material status, latest estimate of physical characteristics, and other pertinent information.

Material Improvement Plan

The Material Improvement Plan (ships) is an annual compilation or plan that establishes a priority order for, and implements and controls the accomplishment of, and budgeting for, alterations in active ships. These alterations are selected from those appearing in, or approved for, inclusion in the Class Improvement Plans of the Ship Improvement Guide.

Operational Improvement Plan

The Operational Improvement Plan (ships) is an annual compilation or plan that establishes a priority and implements and controls the accomplishment of, and budgeting for, nonmilitary alterations in active ships. These alterations are approved by the Bureau of Ships and in general concern matters of safety, efficiency, and economy of operation or upkeep.

AVAILABILITY

The term, availability, is defined in Navy Regulations as "the period of time assigned a ship by competent authority for the uninterrupted accomplishment of work which requires services of a repair activity ashore or afloat."

To say that a ship has been granted an availability means simply that she is available for maintenance work because a competent authority, usually the fleet commander, has suspended her operational schedule for a specific period to permit accomplishment of work at a repair activity. A repair activity may request that availability be extended so that work can be completed or the activity may recommend a completion date to the proper authority.

There are different types of availabilities which vary with the purpose of the availability. They are defined in Navy Regulations as follows.

RESTRICTED AVAILABILITY.—An availability for the accomplishment of specific items of work by a repair activity, normally with the ship present, during which period the ship is rendered incapable of fully performing her assigned mission and tasks due to the nature of the repair work. This availability is assigned to many of the ships that come alongside a repair ship or tender.

TECHNICAL AVAILABILITY.—An availability for the accomplishment of specific items of work by a repair activity, normally with the ship not present, during which period the ship's ability of fully performing her assigned mission and tasks is not affected by the nature of the repair work. This availability is assigned when a unit of auxiliary equipment needs repairs such as a pump, which can be detached and left for repair while the ship continues on her mission. Arrangements must be made for the ship to deliver the defective equipment and to call for it on completion of the repairs, or if the ship is not in the area, to provide shipping instructions.

REGULAR OVERHAUL.—An availability for the accomplishment of general repairs and alterations at a naval shipyard or other shore-based activity, normally scheduled in advance and in accordance with an established cycle. The length of the overhaul and the interval between overhauls vary with different types of ships. Generally, large combatant ships are scheduled to receive a three months' overhaul about every three years.

INTERIM OVERHAUL.—A scheduled availability of not more than one-half the duration of a regular overhaul, for the accomplishment a naval shipyard or other shore-based repair activity of necessary repairs and urgent alterations. Normally, an interim overhaul will be scheduled approximately midway between regular overhauls.

SUPPLY AVAILABILITY.—A period of time assigned a ship by competent authority for the uninterrupted accomplishment of a supply overhaul. A supply availability is normally scheduled to coincide with a regular overhaul.

SUPPLY OVERHAUL.—The work involved in the purification and adjustment of on-board stocks and records to bring them into conformance with prescribed allowances or other stockage objective criteria.

VOYAGE REPAIRS.—Emergency work necessary to enable a ship to continue on its mission

and which can be accomplished without requiring a change in the ship's operating schedule or the general steaming notice in effect. This type of availability is very similar to restricted and technical availabilities, except that a change in operating schedule is not involved.

UPKEEP PERIOD.—A period of time assigned a ship, while moored or anchored, by competent authority for the uninterrupted accomplishment of work by the ship's force or other forces afloat. Ships are assigned upkeep periods at more or less regular intervals, usually between cruises or periods of operations.

REPAIR SHIPS AND TENDERS

The principal difference between repair ships and tenders is that of function. Repair ships are primarily concerned with maintenance in the support of all types of vessels and craft. They are equipped with general maintenance facilities for a number of types of vessels and are provided with stocks of commonly used repair parts. The several classes of repair ships are (1) AR—general duty repair ship, (2) ARB—battle damage repair ship, (3) ARG—internal combustion engine repair ship, (4) ARL—landing craft repair ship, (5) ARS—salvage ship, (6) ARS(D)—salvage lifting ship, and (7) ARS(T)—salvage craft tender.

Tenders render both repair and maintenance to specific types of ships to which they are assigned. They are equipped with facilities for the specific type of ship tended and provided with material that is applicable to the type ship and to the particular class composing the squadron to which the ship is attached. The tender supplies the squadron not only with repair services but also with general stores, medical facilities, ammunition, and often quarters. Tenders are classified as (1) AD—destroyer tender, and (2) AS—submarine tender.

Repair Procedures (Upkeep Period)

Whenever practicable, type commanders arrange routine upkeep periods for their ships alongside a repair ship or tender (normally two week's duration) between regular overhauls. These intervals will vary according to the different types of ships. Small ships, such as destroyers, usually have a tender upkeep period every six months. The upkeep periods are planned to accord with the quarterly employment schedules of the ships concerned. Under normal conditions a ship will know in advance when and where it will go alongside the repair ship or tender.

Work Requests

When a ship receives its employment schedule it can begin preparing the necessary paperwork in advance of the scheduled upkeep period alongside a repair ship or tender. If the Current Ship's Maintenance Project (CSMP) has been maintained properly, writing the work requests is relatively simple. The usual practice is to write the work requests in rough, referring to the appropriate repair record and alteration record cards of the CSMP for the data to be used.

The Repair Record, NavShips 529 (blue) is used to record all repairs that are pending. (Discussed in detail in EM 3 & 2, NavPers 10546-A.) The card is made out as soon as the necessity for a repair tiem or repair job becomes known. A separate card is used for each item in need of repairs, except for small items that are usually included on one card. The cards are filed in the material history binder adjacent to the appropriate material history card until the indicated repairs have been completed.

If authorized alterations are to be accomplished by forces afloat, the data is obtained from the appropriate alteration record card of the CSMP and included with the repair items in the work requests. The Alteration Record, NavShips 530 (pink) is used to record all alterations that are pending. The alteration record cards, similar to the repair record cards, are maintained and kept in the material history binder adjacent to the appropriate history card until the alterations are accomplished.

The data contained on the appropriate CSMP cards are copied onto the work requests for repair ship or tender accomplishment, NavShips 4757, fig. 7-6. At the same time, the ship's serial numbers are assigned to the work requests. The ship's serial number usually consists of three parts, such as DD785-EE2564. The first part is the number of the ship and indicates that it is a work request from DD785. The first letter E, in the second part, indicates that it is a work request from the engineering department; the second letter E indicates that it is an electrical job; and the number 25 is the individual serial number of the electrical job or work request. The last part, 64, of the number indicates the calendar year 1964. In other

RE-READ DIRECTIONS OFTEN – "COMPLETE" REQUESTS GET MORE MAINTENANCE PER DOLLAR OR PER MAN-DAY

1. SHIP (NAME, TYPE, HULL NO.) U. S. S. SEAWAY (DD 785)

2. DATE FIRST WRITTEN 4-15-64

3. WORK REQUEST SER. NO. EE25 64

4. COMPONENT, SYSTEM, ETC. (Item to be worked on) 400 CYCLE MOTORGENERATOR SET #1

5. PRIORITY - URG (A) – A; DES (B) –; SHIP'S 5e

DEPT. PRI. NO. EE2

COG. (BUSHIPS

TYCOM'S / INSURV'S –

INTEGRATED NUMBER

6. WORK REQUESTED (Specify work to be done and/or symptoms of maloperation, etc.)

REMOVE GENERATOR SECTION OF MOTOR-GENERATOR SET #1 FROM SHIP. REWIND 3 PHASE STATOR. CLEAN, DIP, AND BAKE ROTOR (REVOLVING FIELD) WINDING. REINSTALL ON BOARD AND LOAD TEST.

7. LOCATION

COMPARTMENT(S) B-304-E

DECK	FRAME(S)	SIDE
3	112	P

8. JUSTIFICATION AND/OR HISTORY

STATOR WINDING BURNED OUT DUE TO MOISTURE. ROTOR WINDING HAS LOW GROUND READING.

9. STANDARDS OF WORK/CLASS OF REPAIRS: REWIND STATOR

10. REPAIR PARTS KNOWN OR EXPECTED TO BE NEEDED: 2 BALL BEARINGS FSN H5310-106-5084

11. NAME PLATE INFORMATION

GENERATOR DATA:
VOLTS - 120 AC
PHASE - 3
K.W. - 5
CYCLES - 400
C. I. D. NO. 1089072

12. BASIC PLAN NO(S) AND/OR APPLICABLE INSTR. MANUAL (NAVSHIPS NO. IF ASSIGNED): NAVSHIPS 363-0908

AVAILABLE ABOARD? YES: X NO:

13. ASSISTANCE SHIPS FORCE WILL GIVE: ASSIST WITH AND WITNESS TEST

14. WORK PROGRESSED & INSPECTED (FOR SHIP) BY

A.B. SEA - LT (JG)
D.E. EFF - EMC
G.H. EYE - EM1

15. REQUEST DRAFTED BY D.E. EFF - EMC

16. REQUEST REVIEWED & APPROVED BY (FOR SHIP)

17. CHECK IF CONTINUATION SHT. ADDED ☐

18. FLEET SCREENING ACTION

Ship / Via / Tycom

☐ ☐ ☐ SHIPYARD ACCOMPLISH
☐ ☐ ☐ TENDER OR REPAIR SHIP ACCOMPLISH
☐ ☐ ☐ SHIPS FORCE – (TENDER OR R/S) (YARD) ASSIST
☐ ☐ ☐ ACCOMPLISH AS ALT EQUIV. TO REPAIR
☐ ☐ ☐ SHIP TO SHOP
☐ ☐ YARD OPEN & INSPECT – ADVISE TYCOM – PROCEED WITH MINIMUM REPAIRS
☐ ☐ DISAPPROVED OR DEFERRED
☐ ☐ OTHER (SPECIFY) OR REMARKS

19. THIS SPACE FOR REPAIR ACTIVITY'S USE

JOB ORDER NO. / LEAD CODE

ESTIMATED COST (DATE OF EST – ARRIVAL (MINUS) (PLUS) DAYS)

TOTAL M/D / TOTAL DOLLARS $ / LABOR $

MATERIAL $ / OVERHEAD

PREARRIVAL AND/OR ARRIVAL CONFERENCE ACTION – REMARKS

DIRECT CHARGES TO CUSTOMER'S FUNDS

TOTAL $ / TOTAL M/D

NON REIMB. MAT'L (APA) $ / MATERIAL $ / LABOR $

	11	17	23	26	31	35	38	41	51	56	57	64	67	68	71	72	74	99	CODE 300	Other Shops	TOTAL

WORK REQUEST NAVSHIPS 4757 (REV. 4-60)

15.4

Figure 7-6.—Sample rough work request.

words, it is the 25th electrical work request from the engineering department in the year 1964. After all the work requests or items for a group have been written, a priority is assigned each item of work in the group. The requests are then assembled in order of priority for final typing.

The requests, with the required number of copies, are sent with a forwarding letter to the type commander or his representative for screening. The staff officer handling material and maintenance screens the work requests. Most of the times in the ship's work list are approved or authorized. Other work items are recorded so that the ship's force will accomplish most of the work involved. Also, the ship may have to furnish more detailed information on some work requests. The amount of corrective action taken by the reviewing staff officer will depend on how well the work requests are written and whether they follow established policies and procedures. When the screening is completed, the type commander forwards the approved work requests to the repair ship or tender and returns a copy to the ship originating the request.

Generally, the ship must prepare the work requests in sufficient time so that all major work items will reach the repair ship or tender not less than 30 days in advance of arrival alongside. Supplementary work requests, when necessary, should reach the repair activity not less than 10 days in advance of arrival.

Arrival Conference

When a ship arrives at a repair activity, an arrival conference must be held promptly to discuss the work requested by the ship. This conference is attended by representatives of the ship, the repair department, and usually the type commander's representative. The relative needs of the ship and the urgency of each job are discussed. Jobs that were indefinitely stated in the work requests are specifically defined and priorities are established. In other words, the arrival conference serves to clarify all uncertain items for the repair activity, which has received and studied the work requests in advance.

Job Orders

The terms, work requests and job orders, are sometimes used interchangeably. This is not technically correct because the two terms have a different meaning. Work requests are made up by the ship and forwarded through proper channels to a repair ship or naval shipyard. When the work request has been approved by the type commander a job order number is assigned and the work request becomes a job order. The term, job order, is used by repair personnel of a repair ship or tender because it is actually an order to accomplish a certain repair job. Hence, a job order is a work request that has been approved by the repair activity.

Services

The repair ship or tender provides the primary services of auxiliary steam, fresh water, and electric power for a routine upkeep period. Other services such as compressed air or boiler feed water may, in certain cases, be available. Services such as electric power and fresh water are, in most cases, limited, and the auxiliary steam supply is usually insufficient to operate the ship's distilling plant. Therefore, ships alongside must reduce their use of these services as much as possible. The normal procedure is to secure the entire engineering plant when alongside so that repairs can be accomplished without delays or interruptions. During this time, the ship's force should not undertake routine jobs that would interfere with the repair work.

As soon as the work requests have been approved at the arrival conference, the jobs that require delivery to the tender should be started immediately. Getting the repair work started early is very important for the completion of all the repair work on schedule.

All material delivered to the tender must be properly tagged, preferably by means of metal tags secured with wire. The information on the tag should include the number and name of the ship; the department, division, or space; and the job order number. Additional necessary information can be added. Reference material such as blueprints and manufacturers' instruction books should bear the ship's name and number.

Ship-to-Shop Repairs

Many repairs will be designated by the ship or approved by the repair activity as ship-to-shop repairs. This means that the ship's force will do a large part of the repair work. If a motor has a damaged armature winding, the

ship's forces will disassemble the motor and remove the armature. The armature is tagged and carried to the electric shop aboard the repair ship or tender. When necessary, the pertinent blueprints are also delivered to the repair activity. The shop supervisor will estimate the time needed to complete the job. When the armature has been repaired, the ship's force will pick it up at the shop and carry it back to the ship. The motor is reassembled by the ship's force. Inspections and tests are then conducted to ascertain that all conditions are satisfactory.

Repairs for such items as meters, tachometers, and portable equipment are always written up as ship-to-shop jobs. In some cases repairs are written up for a repair activity to assist the ship's force in accomplishing certain repairs.

Progress of Work

The progress of repair work should be checked to be certain that (1) jobs are not delayed, (2) no job is overlooked or forgotten, and (3) all jobs undertaken are satisfactorily completed at the end of the upkeep period.

An Electrician's Mate 1 or C should know at all times the progress of repair work for his space or equipment. He should keep a careful check and estimate on the progress of the ship's force repair work, and check on the progress of the tender repair ship detail. The method of checking the progress of work in the shops on the repair ship or tender may require a little planning and coordination in order not to interfere with the personnel working in the shops.

Repair ships and tenders usually assign a chief petty officer to act as the ship's superintendent. In this case it is easy to check on the progress of work by the tender because the ship will be furnished the necessary information automatically.

The duties of the ship's superintendent are to act as liaison between the ships alongside, and the tender in regard to repair jobs; act as a coordinator of shop work for the assigned ships; report daily to a representative of the commanding officer of the ship to ensure that the work is progressing satisfactorily as far as the ship is concerned; maintain a running daily progress report or chart for each job; notify the ship to pick up completed material on the tender; notify ship's personnel to witness tests on machinery, compartments, and tanks occasioned by work performed; obtain signatures from officers concerned in case of cancellation of a job order; and secure signatures from officers concerned on completion of job orders.

NAVAL SHIPYARDS

The primary purpose of naval shipyards is to render service to the fleet. This service includes efficient and economical building, repairs, alterations, overhauling, docking, converting, and outfitting of vessels.

Naval shipyards are designated as home yards and as planning yards. A home yard is the shipyard to which a vessel is assigned by the Chief of Naval Operations for the accomplishment of overhauls. A planning yard is the shipyard designated by the Bureau of Ships for undertaking the design work for an assigned type of vessel.

Organization

A naval shipyard is under the control of the shipyard commander. The organization includes the (1) management planning and review, (2) industrial relations, (3) public works, (4) supply, (5) comptroller, (6) medical, (7) dental, (8) administrative, (9) planning, and (10) production departments. The planning and production departments are concerned principally with engineering repairs.

The planning department does all the planning in regard to the work requests which are submitted by ships in advance of their overhauls. It prepares cost estimates for each repair requested and issues the job orders for repairs that have received final approval. The job orders include such items as instructions and procedures, reference plans, information on material and repair parts, and shops that are to do the work.

The production department includes the various shops and repair facilities of the shipyard. It is responsible for the execution of work issued by the planning department. It must accomplish this work within the time allowed and with the funds allocated in accordance with applicable instructions and sound engineering practice.

Shops

A shop in a naval shipyard is a separate unit assigned certain specific work, usually by trades, and manned by qualified men adept in

the type of work assigned. A list of the various shops is shown in the following table:

Shop No.	Shop Name
01	Supply Shop
02	Transportation Shop
03	Power Plant
06	Central Tool Shop
07	Public Works Shop
11	Shipfitter Shop
17	Sheetmetal Shop
23	Forge Shop
25	Gas Manufacturing Plant
26	Welding Shop
27	Galvanizing Plant
31	Inside Machine Shop
33	Director Shop
35	Optical Shop
36	Ordnance Shop
37	Electrical Manufacturing Shop
38	Outside Machine Shop
41	Boiler Shop
51	Electric Shop
56	Pipe and Copper Shop
61	Shipwright Shop
63	Joiner Shop
64	Woodworking Shop
67	Electronics Shop
68	Boat Shop
71	Paint Shop
72	Riggers and Laborers Shop
74	Sail Loft
81	Foundry
93	Print Shop
94	Pattern Shop
96	Paint Manufacturing Shop
97	Ropewalk
99	Temporary Service Shop

All production shops in the yard are under the supervision of the production officer through the shop superintendent. Each shop is under the control of a master mechanic. The various ratings of civilian supervisors in the shops and similar activities in the order of responsibility are (1) master, (2) foreman, (3) chief quarterman, (4) quarterman, (5) special leading man, (6) leadingman, and (7) snapper. It will be to your advantage to know the titles of the civilian personnel at naval shipyards when contacting them concerning the various repair jobs.

Ships's Superintendent

The ship's superintendent is a naval officer attached to the production department of the naval shipyard who acts as liaison officer between the ship and the yard. In most yards it is customary to assign one officer as ship's superintendent for each vessel. However, under certain conditions, depending on the size and the number of vessels present, it may be necessary to assign assistants to the ship's superintendent.

The ship's superintendent is usually at the dock when the ship arrives and ties up. He makes certain that the required dock services are promptly furnished. He is one of the first contacts the ship has with yard personnel and maintains this contact throughout the overhaul. He delivers to the commanding officer or the executive officer copies of orders and regulations, which outline and specify procedures mutually affecting the shipyard and the vessel. The subjects covered in the orders and regulations include the requirements for fire watches for various types of work, and general shipyard information for ships.

As soon as the vessel is tied up, the ship's superintendent requests a meeting with the ship's department heads. At this meeting the ship is notified of the time and place of the arrival conference. The ship is also advised of the basic organization and duties of fire watches, and the place and manner of obtaining portable fire extinguishers. Also, the ship is requested to furnish a suitable place on board to serve as an office for the ship's superintendent for the duration of the overhaul.

The primary duties of the ship's superintendent is to assist the ship in all matters regarding repairs when the ship is in the yard. The ship's superintendent maintains a close relationship with the ship's officers, civilian planners assigned to the ship, shop supervisors, supervisors in charge of repair details on the ship, and other naval shipyard supervisory personnel. When delays or interferences develop on a job, he contacts the responsible yard personnel and assists in overcoming any difficulties that may be present. He also keeps the ship's key personnel posted on the progress of all repair jobs. He is available for advice on repair procedures, the quality of work by yard personnel, and tests made by the shipyard.

Ship's Progressman

The ship's progressman is a civilian assigned to the production department of the naval shipyard who keeps a running check on the progress of all yard work being done on the

ship. The usual practice is to assign one progressman to each ship, but under certain conditions it may be necessary to assign assistants to help with the workload.

In addition to keeping the production department informed, the ship's progressman keeps the ship posted on the progress of each job. An experienced ship's progressman, especially for a small ship, will perform most of the duties assigned to the ship's superintendent. Because of his experience and knowledge of the yard he is capable of giving assistance, advice, and information concerning any repair problems.

REPAIR PROCEDURES (REGULAR OVERHAUL)

The Chief of Naval Operations has delegated the authority to the fleet commanders to grant availabilities at naval shipyards for regular overhauls, voyage repairs, emergency repairs, technical availabilities, restricted availabilities, and interim availabilities. The fleet commanders have delegated the authority to type commanders to grant availabilities for voyage repairs, technical availabilities and, in some cases restricted and interim availabilities.

A preliminary determination of the nature and extent of the repair work to be performed on a ship during a regular overhaul must be made by the authority allotting the funds to cover the cost of repair work. The funds to cover the cost of the repairs and alterations to be undertaken must be allotted to the repair activity either by the bureaus concerned or by the commander administering the funds allocated by the bureaus for the purpose.

Ships are assigned regular overhaul availabilities based on the recommendations of the fleet and type commanders concerned. The length of the overhaul varies with the different types of ships. Usually, large combatant ships are scheduled to undergo a four to six week's interim availability every 18 months and three month's overhaul every 36 months.

When the overhaul periods are established for each type of ship, the type commander prepares the regular overhaul schedule for each ship of his force and forwards it to the fleet commander. The fleet commander, after appropriate action, forwards the combined regular overhaul schedule to the Chief of Naval Operations for approval. The type commander then requires his ships to submit their respective work requests, transfers the funds to the appropriate shipyard, the directs his ships to report at the required date to the shipyard.

Work Requests

When a ship has been assigned availability for regular overhaul, the commanding officer of the ship must submit requests for the accomplishment of all repairs and authorized alterations, which are beyond the capacity of the ship's force. The engineer officer is responsible for the preparation and priority listing of repair requests and for the integration and coordination of the ship's force and shipyard work for the hull, machinery, and equipment under the cognizance of the Bureau of Ships.

Work requests should be carefully worded, (fig. 7-6), to enable the shipyard to conduct advance planning and estimating. The requests should accurately describe existing conditions or symptoms that can be used to analyze the fault and determine the general extent of replacement parts and the work required. Nameplate data, drawing numbers, and the status, if known, of special material required for the repairs and alterations should be included.

The work requests must be submitted in accordance with, the specific instructions of the appropriate fleet and type commanders. The prescribed procedure for submitting work requests to shipyards differs somewhat between the Atlantic and Pacific Fleets.

The Pacific Fleet procedure requires the ships to submit a minimum of one original and six copies of the work requests to the type commander 60 days prior to a scheduled regular overhaul. The type commander reviews the work requests, indicating the items to be accomplished by the shipyard, the ship's force, and which are to be deferred or canceled. He then forwards the original and two copies of the work requests in time to reach the shipyard 30 days before the commencement of overhaul, retaining one copy for his file and returning one copy to the ship originating the work requests.

The items of work are grouped and designated as (1) hull (c), (2) machinery (s), (3) electrical (e), (4) electronics (er) including ordnance electronic repairs, and (5) ordnance (r). The items of work must be in the order of priority for each work list of the several groups. After the work lists have been completed, a ship's master priority list, or index,

is prepared and submitted with the work requests. The priority index is usually made up at a conference of all heads of departments and the executive officer. The various items are selected from the individual repair lists (groups) and assigned in an overall, or integrated, order of priority for the ship. The ship's priority index usually consists of the integrated priority, group priority, and title of the job as follows:

Ship's Integrated Priority	Group Priority	Title of Job
1	1c	Drydock ship
2	1s	Lift turbine casing
3	2s	Repair main thrust bearing
4	1e	Repair steering engine motor
etc.	etc.	etc.

A ship's force work list arranged in groups according to that described for shipyard work items must be submitted with the shipyard work requests and the master priority list. This list must show what work the ship's force intends to undertake during the overhaul and what shipyard assistance will be required in the nature of special tools and material.

Supplementary Work Requests

It is sometimes necessary to prepare supplementary work request to include items that occur subsequent to the submission of the original lists. This additional work may be the result of recent voyage casualties or of conditions discovered during shipyard tests and inspections. If possible, supplementary work lists should be prepared prior to the ship's arrival at the yard.

In the Atlantic Fleet all supplementary work lists are submitted to the shipyard via the type commander. If additional funds are required to accomplish urgent supplementary work, the shipyard commander refers the matter to the type commander.

In the Pacific Fleet, except when the type commander or his representative is in the immediate area, supplementary repair requests for work necessary after arrival at the shipyard are submitted directly to the shipyard commander. Supplementary repair requests necessary between the submission of the original repair requests and the ship's arrival at the yard are submitted via the type commander with copies to the shipyard, provided they will reach the type commander at least one week prior to the start of overhaul. Otherwise, the supplementary work requests are submitted in the same manner as those covering work discovered after arrival at the shipyard.

Authorization of Alterations

The Bureau of Ships reviews the alterations outstanding for individual ships in advance of scheduled overhauls. The alterations to be accomplished will be selected from the Material Improvement Plan (Ships) and the Operational Improvement Plan (Ships), giving due consideration to the relative priorities as listed and to the budgetary or fiscal limitations.

The alterations to be accomplished will be delineated according to priority in authorization letters issued by the Bureau of Ships to the shipyard, type commander, and the ship not less than 90 days prior to the starting date of the ship's overhaul. The funds, based on shipyard estimates, are provided by the Bureau of Ships. Additional alterations will not be authorized after issuance of the "90-day letter" unless required by compelling circumstances, such as unforeseen delay in plans or special materials, or special representations by the forces afloat.

The Bureau of Ships, prior to the above procedure, usually provides the type commander with a prospective priority list of the alterations to be accomplished on the ship during the regular overhaul. The type commander may request recommendations from the ship concerned with respect to the ShipAlts that should be completed during the shipyard availability. Also, the type commander may submit to the Bureau of Ships recommended changes in the ShipAlt priority.

Miscellaneous Plans

Several weeks in advance of the scheduled overhaul, the engineer officer should provide instructions to all hands in his department on the objectives to be accomplished during the overhaul and the part to be played by each individual in attaining these objectives. He must

provide for the preparation of plans to cover the ship's force work, training, leave, and security during the availability at the shipyard.

The SHIP'S FORCE WORK includes all work within the capacity of the ship's force. A schedule of the ship's force work includes the names of the individuals responsible for accomplishment, estimated date of completion, estimated number of man-hours required, and the assistance required from the yard with respect to materials and tools. As previously stated, copies of the ship's force work list must accompany the repair requests or work lists when submitted to the shipyard.

The TRAINING of personnel during the overhaul period includes plans that outline the objectives to be accomplished by the end of the availability. The ship utilizes the local training facilities and Fleet schools to the maximum degree consistent with attaining a good overhaul.

The LEAVE accrued while the ship was in an operational status can be used during the shipyard overhaul period. The plans should provide for an equitable distribution of leave to personnel while maintaining a ship's force of experienced inspectors to ensure that the work is satisfactory. A period of turnover should be arranged between the return of one leave party and the departure of another.

The SECURITY of the ship while undergoing overhaul is of prime importance. Special precautions must be taken to prevent fire, flooding, theft, and sabotage. The shipyard is prepared to give assistance in matters of security, but the ship is responsible for establishing security measures.

The greatest continuous hazard to ships in the yard is fire. The disruption of the ship's fire-fighting facilities when burning or welding work is in progress is the most dangerous condition contributing to fire hazards. The ship must provide properly instructed fire watches for each burning or welding job in progress aboard ship. All watch personnel should be instructed regarding the location of shipyard fire alarm boxes in the vicinity of the ship and the current shipyard directives concerning fires and fire fighting.

The possibility of flooding the engineering spaces through sea connections or through leaks in the piping system must not be overlooked. The security plan should require frequent inspections to be made of all unattended spaces in which the possibility of flooding exists.

The responsibility for security of the ship against theft or sabotage depends to a great extent on the security watches and the ship's inspectors of the work performed by the yard. Tact should be exercised in enforcing certain security measures in order not to offend the shipyard personnel. Such measures as routine checking of all lunch boxes and tool kits, which are brought aboard and taken off the ship, cause reactions to the detriment of overhaul work if not done through shipyard authorities. Tools, valuables, and clothing should be placed in locked stowage to reduce the possibility of theft. Also, vigilance should be maintained to prevent the acquisition of shipyard tools by the ship's force.

Acts of sabotage are best counteracted by the vigilance of watch and duty personnel. Irregular patrols through the ship's spaces and proper identification of all personnel boarding the ship are basic requirements for security.

Arrival Conference

When the ship arrives in the shipyard for a regular overhaul, an arrival conference is held either onboard the ship or in the yard. The conference is usually attended by the type commander or his representative, the ship's officers (commanding officer, executive officer, and department heads), the planning officer or planning and estimating superintendent, the type deck officer and his assistant, the ship's superintendent and progressman, and various other directly concerned personnel.

The ship's repair request and priority list are frequently referred to with respect to details, but the principal guiding document for the conference is the Arrival Conference Booklet complied by the planning department. This booklet contains cost estimates of repair and alteration items and other important data concerning the overall planning for the overhaul. The shipyard usually sends copies of the booklet to the type commander and the ship in advance of this conference.

All items contained in the Arrival Conference Booklet are reviewed in order of priority and estimated costs. The total number of items indicates the number of jobs on the work list that can be undertaken within the funds available. When the estimated total cost of the repair items approximately equals the amount of funds appropriated, the cutoff point is reached and the yard will not accept any more repair jobs. The

cutoff point is frequently reached before certain urgent repairs have been covered. In this case, the type commander may provide the extra funds or he may rearrange the individual items in question and revise the priority list accordingly.

Establishing the cutoff point enables the shipyard to make certain the MUST repairs and alterations are accomplished during the availability period. This does not necessarily imply that other items farther down the priority list will not be undertaken and accomplished before the end of the overhaul period. For example, after the ship has been placed in drydock it may be found that anticipated repairs to the shafting and propeller will not be required, and the funds reserved for this work can be used to finance other items. Sometimes a job may be seriously underestimated because of conditions that were not apparent until the job was well underway and funds would not be available to cover the added cost of the work. Under such circumstances, the necessary funds may be provided by deferring other approved items of less relative importance.

Also established at the arrival conference are tentative dates for drydocking, the operation of the main propulsion machinery and associated auxiliaries, and dock and sea trials. The holders of the Arrival Conference Booklet are notified of any changes immediately after the conference in order that all individuals concerned may be kept currently informed. The Bureau of Ships is also informed of the number of shipalts to be undertaken and the estimated cost of each.

When agreement has been reached at the arrival conference on the items of work to be undertaken, the planning department issues job orders authorizing the work to be performed by the production shops. Each job order clearly defines the scope of the work, includes complete specifications, and identifies the necessary plans. Job orders are not issued for all work at the same time. The first to be issued are for those jobs requiring practically the entire availability period. The other orders are issued as soon as possible thereafter. If design plans are required for the accomplishment of any specific item, the issue date of the job order is coordinated with the plan completion date. In any case, job orders for all items approved at the arrival conference are usually issued by the time the one-third point has been reached in the overhaul period.

The method of numbering job orders differs somewhat in the several naval shipyards. However, the numbering systems are essentially the same for the purpose of identifying a particular item of work by a job order number. In addition to the naval shipyard job order number, the job order sheets contain a space into which is entered the ship's work request or work item number for identification purposes.

Assist Ship's Force Job Orders

An assist ship's force job order is issued for each ship undergoing overhaul. It carries an estimate of from \$200 to \$1000, depending on the size of the ship. The purpose is to furnish a drawing account against which the ship can draw for yard assistance when performing work scheduled for the ship's force. For example, it can be used to obtain the services of a welder for a few days to perform miscellaneous welding jobs incidental to the ship's force work. Requests for labor services against this job order are made to the ship's superintendent who prepares a work memorandum to the shop involved. The engineer officer is usually delegated the authority to control the ship's use of the Assist Ship's Force Job Order.

Progress of Work

During a routine naval shipyard overhaul the ship is required to submit weekly progress reports in accordance with the type commander's instructions. In order to submit the weekly progress reports, the ship's supervisory personnel maintain a work progress chart. Any number of copies can be used, as necessary, but usually one progress chart is maintained for the shipyard work and another for the ship's force work.

A shipyard work progress chart (fig. 7-7), identifies each job order by work request number, job order number, and descriptive title of the work. The names of the ship's inspectors for each job are also listed on the charts. The ship's inspectors are required to fill in the percentage of progress and date for each job at least once a week during the early part of the overhaul and several times a week during the later stages, particularly on critical work.

Once a week throughout the overhaul period, the commanding officer of the ship meets with the production officer and other naval shipyard department heads, the ship's superintendent, and

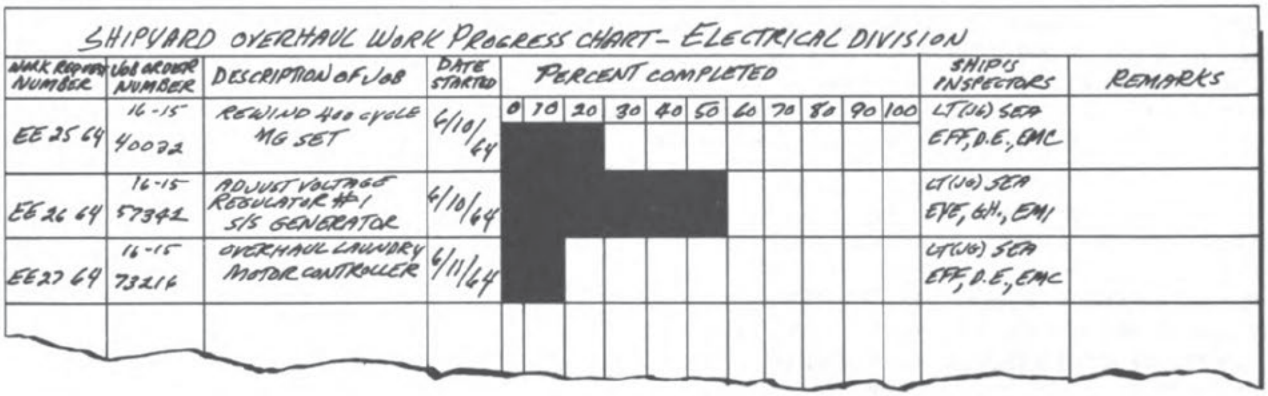

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Figure 7-7.—Sample work progress chart.

master mechanics to discuss the progress being made. The topics discussed at the conferences usually include jobs encountering delays or other difficulties, additional work uncovered, the quality of work being done, and the availability of critical material.

Ship's Force Inspection Duties

The inspection of work on a ship by the shipyard is the responsibility of both the shipyard and the ship. The shipyard requires such inspections that will ensure the proper execution of the work and the adherence to prescribed specifications and methods.

The ship makes such inspections as necessary to determine the satisfactory progress and completion of the work. The ship's inspectors check the progress of work performed by yard personnel in their spaces aboard ship. They also check the progress of work (performed in the shops) on equipment for which they have responsibility. They should check to determine if any tests are required to be made by the yard before the job is considered fully completed. The naval shipyard job order will list any tests that have to be made by yard personnel. The ship's inspectors must witness and verify the results of all important shipboard and shop tests in connection with work under their cognizance.

On many ships it is customary for the division officer or the engineer officer to check with the ship's inspectors before he signs a job order as being completed. The ship's inspectors can furnish the required information without unnecessary delay by a continuous inspection of the shipyard work and by checking off jobs satisfactorily completed.

Report of Unsatisfactory Work

In the event of unsatisfactory work or progress, the ship's inspectors can usually correct the difficulty by discussing it with the yard workmen. If not, they should notify the division officer or engineer officer who in turn can discuss the problem with the ship's superintendent.

Drydocking

The ship is drydocked each time it goes to a naval shipyard for a regular overhaul. It is customary for the shipyard to schedule the drydocking of the ship as early as possible in the overhaul period to ensure completion of all required drydock work (the extent of this work cannot be definitely determined until after the ship is drydocked), and to avoid interference with other work, which must of a necessity be performed late in the overhaul (such as machinery trials and strength tests of structural work).

In preparing for the drydocking, the engineer officer is required to furnish the shipyard with a sea valve checkoff list, indicating the size, location, and function of each sea valve. He is also required to furnish the yard with the ship's

docking plan and, if the ship was last drydocked in a different shipyard, the last docking report. The shipyard maintains in its files copies of the docking plans for each ship which it is expected to drydock. However, it is necessary to check these plans against the ship's copy to note any corrections to reflect work done elsewhere.

While the ship is in drydock, no weight or ballast can be shifted, added, or removed, except as specifically authorized by the docking officer. Any tanks containing water or oil should be either completely full or completely empty. It is the responsibility of the commanding officer to keep an accurate record of the amount and location of any weight changes authorized by the yard.

The propellers must not be turned without permission of the docking officer from the time the vessel enters the dock. No fuel oil, gasoline, or other flammable liquid may be drained or pumped into the dock. If the need arises, the yard will provide special containers for the disposal of these liquids. During freezing weather, all pipes, valves, and fittings attached to the shell should be drained to prevent freezing and possible cracking of the fittings.

When the ship is drydocked, all sea valves must be examined and all necessary repairs should be made to place them in good condition. At the end of working hours each day, openings in the hull (caused by the ship's force disassembling sea valves) should be closed temporarily by replacing the valve bonnets or by blank-flanging the openings. The docking activity is responsible for openings on which it is making repairs. At the end of each working day a report should be made to the engineer officer regarding the status of all sea valves. The same information should be entered in the engineering log.

During flooding and until after the ship is waterborne, all sea connections and any part of the hull on which work was performed must be carefully inspected to ensure that they are properly secured. The inspection must be made by the ship's force as well as by the yard personnel responsible for the repairs effected. Any unsatisfactory conditions must be reported immediately to the engineer office so that the docking officer can be notified in sufficient time to stop flooding, if necessary, before the ship lifts from the supporting blocks.

Docking Report

Shortly after the undocking of a vessel, the shipyard submits the docking report to the Bureau of Ships with copies to the commanding officer and type commander. The docking report includes the name and class of vessel; place and date of docking and undocking; draft readings at docking and undocking; number of days underway, not underway, and waterborne since last docking; the formula and extent of bottom painting; shaft and rudder clearances; and details of all other work performed.

Post-Repair Machinery Tests

Several weeks prior to the scheduled termination of the availability, the shipyard sets a definite date for the completion of all work aboard the ship. The engineer officer should plan and conduct post-repair tests of machinery and equipment in coordination with the ship's superintendent as early as practicable to allow sufficient time to correct any defects discovered during the tests.

Dock Trial

A dock trial is held whenever major repairs have been made to propulsion machinery by a naval shipyard. The trial is usually held as a precautionary procedure at the completion of a regular shipyard overhaul period.

At least one day prior to the dock trial all auxiliary machinery is tested to prevent delay or interference with the testing of the main engines and associated equipment. The engineer officer directs tests of boilers and machinery (with the ship properly secured to the dock) to ascertain that the equipment is ready for operation at sea. Sufficient tests and inspections are made to ensure that machinery and equipment have been properly repaired and are in good operating condition. Any defect, deficiency, or maladjustment must be corrected either by the ship's force or the shipyard. The dock trial is repeated as often as necessary until conditions are satisfactory.

POST-REPAIR TRIAL.—A post-repair trial is mandatory when the machinery of a vessel has undergone extensive overhaul, repair, or alteration, which may affect the power or capabilities of the vessel or the machinery. On the other hand, when the machinery has undergone only

partial overhaul or repair, the necessity for a post-repair trial is determined by the shipyard commander. The object of the trial is to ascertain if the work has been completely and efficiently performed and if the machinery in all its parts is ready for service.

The post-repair trial is held as soon as practicable after the repair work has been completed, the preliminary dock trial made, and the persons responsible for the efficiency of the work are satisfied that the machinery is in all respects ready for a sea trial. The trial is conducted by the ship's force and may be witnessed by representatives of the naval shipyard. The conditions of the trial are largely determined by the character of the work performed. The trial should be conducted in such a manner as considered necessary and sufficient by the commanding officer.

A full-power trial, if required, should be conducted during the post-repair trial. However, the commanding officer can delay this trial if he considers a wear-in period necessary for new parts such as bearings or reduction gears.

As soon as practicable after the completion of the post-repair trial the commanding officer will designate certain parts of the machinery to be disconnected, opened up, and carefully examined to determine the extent of any injury, defect, or maladjustment, which may have occurred during the trial. Any unsatisfactory conditions must be corrected by the shipyard if they are beyond the capacity of the ship's force.

A report is required only when, in the opinion of the commanding officer or the shipyard commander, the machinery does not operate satisfactorily at the conclusion of the regular overhaul period. This report, in letter form with any substantiating data appended as enclosures, can be originated by either the commanding officer or the shipyard commander. If originated by the commanding officer, it is forwarded via the shipyard. If the shipyard originates the report, copies are sent to the ship and the type commander.

Fueling

Ordinarily, fueling of ships in naval shipyards is not permitted during regular working hours because it would interfere with hot work on board ships. If it is necessary to take on fuel prior to the readiness-for-sea period, the engineer officer should make arrangements with the fueling activity to have the fuel delivered after normal working hours. These arrangements must be cleared through the shipyard security officer.

Readiness-For-Sea Period

A basic readiness-for-sea (RFS) period of seven days is established for all active ships commencing immediately after completion of a regular shipyard overhaul period. The RFS period may be varied by the type commander as necessary for a specific ship. An RFS period is assigned for the specific purpose of providing the commanding officer with sufficient time for preparing the ship for sea. Therefore, shipyard work must not be performed during this period unless it is of a most urgent nature and authorized by the type commander.

The plans for the RFS period should provide for the timely accomplishment of degaussing and deperming, if required; compensation of magnetic compasses; radar range calibration; calibration of radio direction finder; structural test firing of newly installed armament; operation at sea for machinery tests; loading of ammunition; completion of loading of equipage, repair parts, stores, provisions, and fuel; and other required adjustment and calibration of the ship's equipment.

FAILURE REPORTS

A Report of Equipment Failure form (NavShips 3621, fig. 7-8) must be submitted to BuShips as soon as practicable after the accomplishment of any repair to installed shipboard machinery or equipment (except electronic) under the cognizance of BuShips. This form replaces the old Material Analysis Data form and is designed to aid the bureau in evaluating the performance and reliability of machinery and hull equipment.

An instruction sheet is furnished with the forms. Read these instructions carefully before preparing the form. List federal stock numbers for any parts or material referred to if available, and make your remarks and recommendations as specific and clear as possible. If the cause of failure is unknown, a design deficiency is suspected, or a recommendation for further

REPORT OF EQUIPMENT FAILURE
NAVSHIPS 3621 (Rev. 6-59)

REPORT BUSHIPS-9120-1

1. SHIP TYPE	2. HULL NUMBER	3. DATE OF FAILURE (MONTH, DAY, YEAR)	4. DATE OF LAST FAILURE (MONTH, DAY, YEAR)
AKA	80	3-22-62	12-1-61

NAME OF FAILED COMPONENT: GENERATOR IC MOTORGENERATOR SET #2

5. COMPONENT ALLOWANCE GROUP NUMBER: 563

6. COMPONENT IDENTIFICATION NO. (CID): 18107003

COMPONENT MANUFACTURER'S NAME: BURKE ELECT. CO.

7. MANUFACTURER'S SERIAL NUMBER: 149514

8. NUMBER OF MAINTENANCE CHECKS SINCE LAST FAILURE.	9. DID COMPONENT FAIL IN OPERATION?	10. OPERATIONAL HOURS SINCE COMPONENT LAST FAILED.
20	☒ YES ☐ NO	1500

CAUSE OF FAILURE (CHECK ONE)

1. ☐ BROKEN OR CRACKED PART	5. ☐ FAILURE OF WELD.	9. ☐ LOOSE CONNECTION	13. ☐ LEAK
2. ☐ EXCESSIVE PART CLEARANCE	6. ☐ LACK OF LUBRICATION	10. ☐ INSULATION FAILURE	14. ☐ FUNGUS
3. ☐ FAILURE OF CONTROL	7. ☐ IMPROPERLY INSTALLED	11. ☐ WATER	15. ☐ CORROSION
4. ☐ FOREIGN MATTER	8. ☐ EXCESSIVE HEAT	12. ☐ VIBRATION	16. ☒ UNKNOWN
	17. ☐ OTHER (SPECIFY)		

PART DATA

NAME OF PART THAT FAILED	MATERIAL OF WHICH PART IS MADE	HOURS OPERATIVE	PART NO. (USE ONLY ONE) FEDERAL STOCK NO. BUREAU PLAN OR PIECE NO. OR MCF NO.
COLLECTOR RING ASSEMBLY	BRONZE	1500	H 5977-101-1760

REMARKS AND RECOMMENDATIONS

Give description of failure, elaborate on cause and/or remedy as appropriate. Give recommendations to prevent recurrence

CENTER COLLECTOR RING GROOVED AND PITTED OVER AN AREA SPANNING 120 DEGREES REQUIRING REPLACEMENT OF COLLECTOR RING ASSEMBLY. IDENTICAL FAILURE OCCURRED TO #1 M.G. SET 6-3-61. STOCK NO. FOR BRUSHES INSTALLED IS H 5977-206-1871. REQUEST FURTHER STUDY AND RECOMMENDATIONS.

SIGNED	DATE

G11135

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Figure 7-8.—Sample equipment failure report.

study by the bureau is requested, all evidence of the failure (damaged parts, etc.) must be kept for 60 days after the report is submitted or until disposal instructions are received from the bureau. Failure reports are not required for routine maintenance repairs unless there is reason to believe that conditions other than normal wear and tear exist.

CHAPTER 8

INSPECTIONS AND TRIALS

This chapter describes the various types of inspections of ships as they apply to the engineering department. Following this description, full power and economy trials are discussed.

INSPECTIONS

Inspections are necessary to ensure that naval vessels are maintained at a high standard of readiness.

The frequency of the administrative, operational readiness, and material inspections is determined by the Chief of Naval Operations, Fleet Commander, and Type Commander. The Type Commander will usually designate the type and date of an inspection of a ship.

Notification is generally given in advance of an inspection. This is not to mean that a ship can delay preparations until such a notice is given, as a poorly run ship can never be made ready in time to pass the inspection. A continuous program of repair, maintenance, and operating procedures is the only way to pass an inspection. This includes keeping up to date the maintenance records for the engineering department, and other related records and reports. Training personnel and conducting engineering casualty control drills are also important.

Your ship may be required to furnish the inspecting party that will make an inspection of another ship. You as an EM1 or C may be assigned the duty of an assistant inspector. Therefore, you should know something about the different types of inspections and how they are conducted.

ADMINISTRATIVE INSPECTION

Administrative inspections cover the general administration of the ship as a whole and the administration of each department. This discussion will apply mainly to the engineering department.

An administrative inspection tries to answer two questions. These are:

1. Is the engineering department being administered in an intelligent, sound, and efficient manner?

2. Are the organizational and administrative methods and procedures directed toward the objective of every naval ship, namely, the readiness to carry out her intended mission?

Inspecting Party

The routine procedure is for one ship to conduct an inspection of another ship of the type. General instructions for conducting the inspection are usually given by the type commanner. The selecting and organizing of the inspecting party is done aboard the ship that has received instructions to assist in the inspection.

The Chief Inspector, usually the commanding officer of the ship, will organize the inspecting party. The organization of the assisting board is in general conformance with the departmental organization of the ship. It is divided into appropriate groups, each headed by an inspector with assistant inspectors as necessary. Chief petty officers are usually selected as assistant inspectors, and on small ships, other petty officers may be assigned duties as assistant inspectors.

The engineering department inspecting group (or party) is organized and supervised by the engineer officer. The manner in which the inspection is carried out will depend to a great extent upon the knowledge and ability of the assistant inspectors.

General Inspection of the Ship

One of the two categories of the administrative inspection is that of the general administration of the ship as a whole. Items of this inspection that will have a direct bearing on the engineering department, and for which the report of inspection indicates a grade, are as follows:

1. Appearance, bearing, and smartness of personnel.
2. Cleanliness, sanitation, smartness, and appearance of the ship as a whole.
3. Adequacy and condition of clothing and equipment of personnel.
4. General knowledge of personnel in regard to the ship's organization, ship's orders, and administrative procedures.
5. Dissemination of all necessary information among the personnel.
6. Indoctrination of newly reported personnel.
7. General educational facilities for individuals.
8. Comfort and conveniences of living spaces, including adequacy of light, heat, ventilation, and fresh water, with due regard for economy.

Inspection of Engineering Department

The detailed inspection of the ship includes all supplementary inspections by the senior inspectors and their respective departmental inspectors in both ship wide and departmental or subdepartmental items. The detailed inspection of the various elements may commence before, during, or after the general inspection, as directed by the chief inspector. They must not, however, interfere with, or prejudice, the chief inspector.

The departmental checkoff lists are prepared in a form intended to simplify the ship's task of preparing fully for an administrative inspection. Each question is phrased, when possible, to be answered with "yes" or "no" to signify a satisfactory or unsatisfactory condition respectively. It is not expected or intended that the inspecting party check each item listed in the checkoff lists. The inspecting party will, however, investigate as many items as practicable during the time allotted, stating in its reports to the chief inspector the number of items checked, the number of discrepancies noted, and a recommended grade based on personal observation.

As a petty officer, you should be familiar with the various checkoff lists used for inspections. The checkoff lists will give you a good understanding of how to prepare for an inspection as well as how to carry out your daily supervisory duties. You will find it helpful to obtain copies of the various inspection checkoff lists from the log room and to carefully look them over. They will give detailed information for your type of ship.

You can get a better understanding of the scope and purpose of administrative inspections, as compared to other types of inspections, from the inspection checkoff lists.

After the general and detailed inspections have been completed, the chief inspector usually conducts a precritique conference with the senior inspectors. At this conference findings and recommendations are correlated, and grades assigned and recorded for the general and detailed inspections on the administrative inspection summary.

The grades for items of the general inspection assigned by the chief inspector are to be interpreted as applicable to the overall shipwide standards displayed in matters of shipwide applicability. The grades for items of the detailed inspection assigned by the senior inspectors are applicable to the indicated organizational subdivisions and observed in detail by the departmental inspectors. Fixed marks are assigned the various sections based on the findings of the inspection of details made in accordance with the administrative checkoff list.

The appraisals of an inspection should be limited to one of the following broad classifications:

	BROAD CLASSIFICATION	EQUIVALENT NUMERICAL GRADE
1.	Outstanding (Fully ready in all respects and NO known superior in this type)	100 - 95
2.	Excellent (No vital and few minor deficiencies. So markedly above required minimum standard as to be among the few best)	94.9 - 88

	BROAD CLASSIFICATION	EQUIVALENT NUMERICAL GRADE
3.	Good (Possibly some deficiencies but no critical ones. Above the required minimum)	87.9 - 75
4.	Satisfactory (At the required minimum, capable of performing assigned functions)	74.9 - 62
5.	Unsatisfactory (Below the required minimum in general or in any vital particular.)	61.9 - 0

Post Inspection Critique

The critique of the administrative inspection is held on board the inspected ship as soon as practicable after the precritique conference. It is attended by all the inspected ship's officers and appropriate leading petty officers, the chief inspector, and senior and departmental inspectors. The chief inspector comments on the overall conduct of the inspection, including discrepancies and deficiencies of material or procedure, and makes recommendations for the improvement of personnel performance or of material. Reports of the administrative inspection are sent to the type commander via the inspected ship. The administrative inspection checkoff list filled in for items inspected are retained by the inspected ship.

After the critique, the chief inspector prepares a report in the form of a letter, which is forwarded to the type commander via the commanding officer of the inspected ship. The letter contains the numerical merit obtained by the ship during the administrative inspection and a statement of whether the ship is or is not considered an effective unit of the fleet.

The letter includes a copy to each endorsee of the inspection summary. If the inspection is outstanding or unsatisfactory, the original and two copies of the inspection summary are forwarded to the type commander. Also, included in the letter is a report of an inspection of the registered publications (RPS).

Operational Readiness Inspection

The operational readiness inspection consists of a demonstration on the part of the ship of its readiness and ability to perform the operations that are required in time of war. The inspection will comprise the conduct of a battle problem, including damage control, engineering casualty control, and other appropriate exercises. Drills, such as Man Overboard, Preparations to Abandon Ship, Fire, and Collision will be held and observed.

The objective of the inspection is to determine that the ship as a whole can carry out its operational functions; that the ship's company is well trained, competent, and adept in all phases of evolutions; and that the ship's company is stationed in accordance with the ship's Battle Bill.

Observing Party

The organization of the operational readiness observing party is very similar to that of the administrative inspecting party. The size of the observing party will vary, depending on the size of the ship to be exercised, the type and extent of the battle problem, and the number and methods of introducing the disclosures. The observing party should be composed of personnel required to make the disclosures with additional personnel at as many stations as possible to witness and evaluate performances.

The chief observer will supervise the preparation of the battle problem by the battle problem board. He will transmit to the commanding officer, in advance of the scheduled exercises, instructions for the conduct of the problem. These instructions will include the problem operation order, authority for conducting the problem, time of boarding by observers, underway time, time of setting designated material conditions, time for conducting inspections prior to zero problem time, zero problem time, end of problem time, and time of critique.

Adequate copies of the instructions will be furnished the exercise ship to permit study, dissemination of pertinent parts to appropriate

personnel, and preparation of a digest for indoctrination of all hands.

The members of the observing party should be proficient in the particular field they represent and well versed in the latest practices and directives applicable to their specialty. Each observer will usually have an assigned station and should be qualified in the procedure of conducting drills and exercises for that station. It is highly desirable that the observers be thoroughly familiar with the capabilities and limitations of the type of vessel to be exercised.

The observers should be briefed in advance of the problem to ensure that they understand the battle problem and their specific duties within its framework. They should be instructed concerning the introduction of disclosure material, which should include sufficient explanation or information to indicate its relation to the whole problem. The observers may resort to coaching if the ship's personnel are unable to discover the imposed casualty within a reasonable length of time. In the event this is done a notation must be made on the reporting form as to the time allowed before coaching or prompting.

The senior engineering observer should have sufficient observers assigned and briefed to ensure that no function of the engineering department will be unobserved. Before the start of the problem he should consult with the engineer officer to determine that his personnel have been properly briefed. He determines the status of the engineering plant and any existing deficiencies that would affect the battle problem. During the battle problem he is stationed at the main engine control and observes the general conduct of the problem and takes notes for his report.

The engineering department observers are assigned a station by the senior engineering observer. They take notes concerning items as required and impose engineering casualties by disclosing symptoms according to the battle problem casualty schedule. They observe the action by the ship's personnel concerning each casualty imposed and note any departures from the prescribed procedures contained in the Bureau of Ships Technical Manual, Ship Exercise Manual, Type Commander's Instructions, and the Ship's Casualty Control Manual. They should note particularly any outstanding performance or deficiencies, including violations of safety precautions.

Battle Problem

A battle problem is a test of the battle organization of a ship. It consists of a series of real or simulated events. These events generally occur within the framework of an imaginary battle situation and require action on the part of the ship's battle organization to counter the threat imposed, including control of extensive simulated damage.

The primary purpose of the battle problem is to provide a medium for testing and evaluating the ability of all departments to function together as a team in simulated combat operations while accomplishing the mission or tasks assigned by the problem, and in handling casualties. There are many operational exercises that provide a better means of testing individual and team performances in specific evolutions; however the battle problem is the only effective exercise that requires all departments to function simultaneously as one team.

The degree of realism governs the value of a battle problem. For this reason it is necessary in the stages of preparation to give thorough attention to the simulation of events.

The engineering plant should be operated in accordance with the requirements of the tactical situation. In order to make equipment casualties apparent, machinery should be stopped, control circuits opened, lights extinguished, power switches pulled, air test cocks opened, valves opened or closed, and hoists stopped. To avoid damage to machinery, however, such action shall be taken by ship's personnel as directed by responsible observers and not by the observers themselves. The supply of lubricating oil to the main plant, boiler feed system, or any other piece of equipment vital to the safe operation of the ship will not be stopped to simulate casualties. Actual use of foam, water, or CO_2 should not be permitted in machinery spaces.

The general announcing system (circuit 1 MC) may be used by the ship's personnel, but the observers will normally have priority in its use to conduct the battle problem. The problem time announcer will use the general announcing system to announce the start of the battle problem, the problem time at regular intervals, the conclusion of the problem, and the restoration of casualties. However, the general announcing system is kept available

at all times for use in case of actual emergency. All other announcing systems and other means of interior communications are reserved for the exclusive use of the ship. The engineering telephone circuits should be monitored by one or more observers. They should check for the proper procedure and circuit discipline, and for the proper handling of information or casualties.

In order to carry out the problem efficiently, the exercise ship should receive considerable information before problem time. At least one week in advance of the problem, exercise ship personnel need to know the time schedule to be followed and in general the equipment that will be affected. Observers will give more specific information to the ship just prior to the start of the battle problem.

When the commanding officer of the exercise ship reports his ship ready for the problem in accordance with the requirements specified in the operation order, an inspection is carried out to determine conditions existing at zero problem time. Normally, the prescribed condition calls for all hands at battle stations with material condition ZEBRA set throughout the ship.

The inspection at zero problem time is made to determine the readiness of the ship for battle. Usually it requires about fifteen minutes to conduct the inspection. It is desirable for each senior observer to report completion to the observer in damage control central who will make a composite report to the chief observer on the bridge.

The engineering items normally checked in the zero problem time inspection include the proper setting of prescribed material conditions in the engineering spaces, segregation of the plant, manning of proper telephone circuits, and standby machinery made ready with unnecessary machinery and nonvital circuits secured.

Any of several situations may indicate the time to start the problem: (1) completion of zero problem time inspection has been reported by senior observers; (2) the exercise ship has reached the prescribed navigational point; (3) proper contact with target service is assured; or (4) the chief observer considers the operational situation appropriate to starting the problem.

Word should be passed over the general announcing system and all sound-powered telephone circuits; "Stand by for zero problem time;" then, after a long blast on the ship's whistle, "mark, zero problem time." The time announcer can pass problem time word over the general announcing system as often as it is desirable-every two minutes works well in practice.

The actual conduct of the problem is relatively simple in contrast to the preparatory stages. During the problem it is expected that all of the training comes into play and the briefings on methods of disclosing information about the simulated hit have prepared participants for the necessary corrective procedures.

The engineering observers introduce the engineering hit disclosures when "hit" is announced, ensure that the general announcing system remains operative throughout the problem, monitor vital telephone circuits, and ensure that safety precautions are observed. They observe and evaluate casualty control procedures, coordination between engineering stations and interdepartmental teamwork, reports made to conn, promptness and effectiveness in restoring maximum boiler and engine power, and extent to which correct engineering practices are followed.

The chief observer will inform the commanding officer of the exercise ship at the completion of the problem and will request that all casualties be restored and that the ship return to base for presentation of the critique. The casualties should be restored before securing from general quarters.

The Critique

Immediately after the battle problem an analysis is made of the results. The purpose of this analysis is to obtain the fullest benefit, both for the ship being inspected and for the combat readiness of the fleet. Analysis is accomplished in two steps: (1) The observers' preliminary reports which are summarized at a critique: a presentation of departmental evaluations of performances demonstrated and recommendations for improvements, and (2) The observers' final written reports.

The critique affords observers an opportunity to present to the ship their evaluation of problem performances (including preliminary

grading). It also affords the exercise ship's personnel an opportunity to comment on the observers' remarks. After the critique, observers prepare a final written report that goes to the commanding officer of the exercise ship, the officer scheduling the exercise, and to appropriate higher authority so that lessons learned and suggested improvements in doctrine or material may be presented to the fleet.

Before discussing the critique any further something should be said concerning the preparation of the critique as it will be presented to the exercise ship.

The time and work that go into preparation for the critique is important. Usually it requires a minimum of one hour for experienced observers to prepare for the critique. Before the critique the departmental observers meet with and submit their reports to their senior observer. The senior observer must then analyze these reports, and combine them for presentation to the chief observer. To aid this analysis, it is important that the reports be clear, concise, and thorough concerning all observed performances. Mistakes made, excessive or excellent time taken for an action, state of training, interdepartmental teamwork, presence or lack of confusion, grasp of the situations and efficiency of actions, demonstrated knowledge of the ship, and interest are all considered. The analysis should indicate good features as well as poor ones, presenting to the ship a comprehensive picture of its performance during the problem and indicating any strong and weak points which contribute significantly to the ship's state of readiness.

A pre-critique conference between departmental observers and key personnel of the ship's respective departments may be greatly beneficial. The problem can be discussed in detail, covering all points and clearing up any misunderstanding that may exist. The critique later on can then be devoted to major facts of the battle problem, without having to deal with minor points.

When the senior observers are prepared, the chief observer will begin the critique. This critique is held aboard the exercise ship before the observing party leaves, while the battle problem is still fresh in the minds of all concerned. It is attended by all ship's officers, appropriate leading enlisted men, the chief observer, and all senior and departmental observers.

The chief observer begins by explaining the purpose of the critique. Each senior observer then summarizes overall performance within his area and introduces his subordinate departmental observers, who present the analysis of the problem as developed from their observer reports.

These presentations should be objective and not a mere recitation of many minor discrepancies. Emphasis should be placed on major discrepancies and fundamental deficiencies which may relate to such areas as assignment of personnel, training, and interior communications. (A list of minor discrepancies may be left with the ship.) Ship's officers may comment during or after the observers' presentations.

When all presentations have been completed the chief observer comments on the overall conduct of the battle problem.

Final reports should be submitted in accordance with type commander's directives. When techniques or methods are observed which will improve combat readiness of the fleet, they should be made the subject of a special letter report.

Exercise reports should include:

1. Comments and criticisms on overall performance.
2. Outstanding or unsatisfactory individual performances.
3. Improvements needed in the battle station arrangements.
4. Suggestions and recommendations resulting from analysis of the complete exercise.

MATERIAL INSPECTIONS

Material inspections are conducted by (1) the Board of Inspection and Survey and (2) the forces afloat.

The Board of Inspection and Survey's routine material inspection is conducted by a specially appointed board consisting of well-seasoned senior officers. The inspection procedures, condition sheets, and reports are all used in establishing directives for the inspection conducted by the forces afloat.

The organization of the Board of Inspection and Survey, as well as a description of many of the types of inspection conducted by the Board is discussed later in this chapter.

You, as a chief or first class petty officer, will be more directly concerned with the preparation and conduct of material inspections by the forces afloat. For this reason, the discussion which follows refers specifically to inspections conducted by the forces afloat, and knowledge you should have concerning the administration of these inspections.

The purpose of the material inspection is to determine the ability of the various items to perform the functions for which they are separately and interrelatedly designed, and to recommend repairs, alterations, or developments necessary to ensure the material readiness of the ship in carrying out its mission. In addition, the material inspection determines whether the proper methods and procedures are used in the care and operation of machinery and equipment.

The distinction between a material inspection and an administrative inspection should be clearly recognized to avoid as much duplication as possible. The material inspection should be thorough and searching to cover detailed maintenance and repair instead of the general appearance of machinery and equipment. The material maintenance records and reports are examined to obtain data and material history for a proper understanding of the material condition of the equipage. The general administrative methods, including appearance and cleanliness of compartments and machinery are not a part of this inspection, except when they have a direct bearing on the material condition.

Inspecting Party

The inspecting party similar to that of the administrative inspecting party consists of a chief inspector with the necessary assisting inspectors.

The chief inspector is responsible for the overall conduct of the inspection. At an appropriate time prior to the inspections he will furnish the ship to be inspected with advance instructions. These instructions will include a list of machinery and equipment to be opened, copies of the condition sheets, and any additional instructions considered necessary by the type commander or other higher authority.

The equipment to be opened must include units of machinery known to be deficient, and the other units selected must be representative. In order not to impair the operational schedule and safety of the ship, the units to be opened must not exceed half of the propulsion units.

The material condition sheets are made up in accordance with the different departmental material groups. The engineering department is primarily concerned with the main propulsion, electrical, damage control, and hull condition sheets. The condition sheets consist of a large number of pages containing material in the form of checkoff sheets and material data sheets. The items for data and checkoff purposes are listed for all parts of the ship and for all machinery and equipment on board the ship.

Preparation for Inspection

Prior to the inspection, each department must prepare work lists showing the items which have been assigned for accomplishment by the ship's force, forces afloat, or naval shipyard during an unkeep period or overhaul. The items must be arranged in the recommended order of importance and numbered according to current directives. A list of the outstanding alterations is also made up for the inspection. The work list should include all maintenance and repair items because material deficiencies found during the inspection will be checked against the work list. If the item does not appear on the work list, a discrepancy in maintaining the Current Ship's Maintenance Project is noted by the inspecting party.

In advance of the inspection, the ship to be inspected must fill in a preliminary copy of the condition sheets with detailed data obtained from Maintenance Records for the Engineering Depart. An entry is made on the condition sheets of any known fault or abnormal condition of machinery or equipment. Then necessary details are included to indicate the material condition to the inspecting party. If corrective work is required in connection with a unit or space, a reference is made to the work list item. The data and information requested in the condition sheets should be furnished whenever possible. The preliminary copy, if properly filled out, will represent the best estimate of the ship concerning its existing material condition.

The completed condition sheets are turned over to the respective members of the inspecting party when they arrive on board the ship. During the inspection, the inspectors will fill in the various checkoff sections of the condition sheets. The sheets are then used in preparing the final inspection report on the condition of the ship.

The material inspection also includes an inspection of the various material records and reports in additon to the machinery and equipment. These documents are assembled so that they will be readily available for the inspecting party. The individual records must be filled out and maintained in accordance with current directives. Where applicable, the chief petty officer in charge of an engineering space or other assignment should check on any records or reports concerning the material or the maintenance procedures for his space or assignment.

Conduct of Inspection

The inspecting group for the engineering department should conduct a thorough and critical inspection of the machinery and equipment under the cognizance of the department. The condition sheets supplied by the type commander serve as a guide and a checkoff list in making the inspection. Appropriate remarks, comments, and recommendations are entered on the condition sheets for the particular unit of machinery or equipment.

The inspectors should conduct the inspection with the appropriate ship's personnel. No attempt is made to follow a predetermined inspection schedule, but different units are inspected as they are made available by the ship's company. If the ship is prepared for the inspection there should be no delay between the inspection of the different units of machinery. It is not necessary to inspect all machinery of a specific type simultaneously or to complete the inspection of one space before inspecting another space.

During the inspection, all opened machinery and equipment is carefully inspected, especially when the need of repair work is indicated on the work list. An investigation should be made to disclose any defects (in addition to those already shown) that may exist in the design or material condition. In accordance with the furnished list, operational tests of machinery and equipment are observed.

Electrical equipment is inspected to ensure that it is not endangered by leaks in piping flanges and by salt water from hatches, doors, of ventilation ducts. The prescribed firefighting and damage control equipment are checked to ensure that it is adequate and properly maintained. The holding-down bolts, plates, and other members of machinery foundations are inspected in addition to the supports and running gear of heavy suspended material, such as boiler sliding feet, condenser saddles, and turbine supports.

The condition sheets are checked to ascertain that all the required information has been filled in by the ship being inspected and that all items have been checked off and filled in by the inspector. The engineering department maintenance records are carefully inspected to determine that they are maintained in accordance with prescribed procedures and that all known repair requirements are listed.

The critique of the material inspection is held on board the inspected ship at a convenient time after completion of the inspection. It is attended by the ship's officers; leading petty officers; and the chief, senior, and departmental inspectors.

The senior inspectors, after receiving data from their respective inspectors, submit reports of their inspections to the chief inspector. These reports provide a means of furnishing the inspected ship with those observations that may not be fully discussed during the critique, but are of interest to the ship's officers. The senior inspectors' reports should include their evaluations and any recommendations for the items inspected or observed. These reports can be used by the ship as a checkoff list for corrective action and material improvement.

After the critique, the chief inspector will prepare his report, using the departmental reports as a basis to evaluate and grade the inspection. The final written report is prepared in accordance with the type commander's directives. It should include comments and appropriate criticisms on conditions requiring remedial action, which should be brought to the attention of the commanding officer and to higher authority, and on conditions of such excellence that their dissemination will be of value in improvements to other ships.

BOARD OF INSPECTION AND SURVEY

Inspections of ships are conducted by the Board of Inspection and Survey, when directed by CNO, to determine their material condition. This inspection usually takes place once in every 3 years. Whenever practicable, such inspections should be held 4 to 6 months in advance of a regular overhaul of the ship to permit accomplishment, during such overhaul, of the authorized work resulting from the Board's

recommendations. Upon the completion of its inspection the Board will report the general condition of the ship and its suitability for further naval service, together with a list of the repairs, alterations, and design changes which, in its opinion, should be made.

The board consists of the President, an East and West Coast Deputy to the President and Boards organized as follows:

A. Permanent Boards, established Naval Activities.
   1. Board of Inspection and Survey, Washington, D. C.
      a. Sub-Board of Inspection and Survey, Newport
      b. Sub-Board of Inspection and Survey, Norfolk
      c. Sub-Board of Inspection and Survey, Pearl Harbor
      d. Sub-Board of Inspection and Survey, Charleston
      e. Board of Inspection and Survey, Washington, D. C. OFFICE, NATC, Patuxent River, Maryland.
   2. Board of Inspection and Survey, Pacific Coast Section, San Diego, California. Sub-Board of Inspection and Survey, San Francisco.

B. Semi-Permanent Boards, temporary additional duty.
   1. Reserve Fleets. Sub-Board of Inspection and Survey in each Reserve Fleet Group.
   2. Naval Districts. Sub-Boards of Inspection and Survey in each Naval District.
   3. U.S. Pacific Fleet
      a. Sub-Board of Inspection and Survey, Yokosuka
      b. Sub-Board of Inspection and Survey, Subic
      c. Sub-Board of Inspection and Survey, Guam

C. The parent Board under the direction of the President and his East Coast Deputy has its Headquarters in Washington, D.C. The West Coast Deputy is the Senior member of Inspection and Survey, Pacific Coast Section with Headquarters in San Diego, California.

Conduct of Inspection and Trials.

The President of the Board of Inspection and Survey arranges for the conduct of a material inspection by any board under his jurisdiction.

Normally, however, these inspections will be conducted by boards as follows:

1. Active Fleet Ships
   Permanent Boards.
2. Reserve Fleet Ships
   Semi-Permanent Boards; i.e., Reserve Fleet Group Sub-Boards.
3. Naval Reserve training ships (all except ships assigned Eighth, Ninth, and Thirteenth Naval Districts):
   Permanent Boards
4. Naval Reserve Training ships (Eighth, Ninth, and Thirteenth Naval Districts):
   Semi-Permanent Boards; i.e., District Sub-Boards.
5. District Craft
   Semi-Permanent Boards; i. e., District Sub-Boards.

Acceptance trials are made by permanent boards.

Acceptance Trials and Inspections

Trials and inspections are conducted by the Board of Inspection and Survey on all ships prior to final acceptance for naval service, to determine whether or not the contract and authorized changes thereto have been satisfactorily fulfilled. These inspections are usually conducted before a new ship is placed in commission. Similar inspections are made on ships that have been converted to other types. All material, performance, and design defects and deficiencies found to exist, either during the trials or as a result of examination on completion of trials, are reported by the Board, together with its opinion as to the responsibility for correction of defects and deficiencies. The Board will recommend any changes in design which it believes should be made in the ship or in others of its type. Recommendations as to the acceptance or rejection of the ship is made to the Secretary of the Navy.

Unless war circumstances prevent, the preliminary acceptance trial takes place at sea over an established trial course. Tests include full power runs ahead and astern, quick reverse, boiler overload, steering, and anchor engine. During the trial, the builder's personnel usually operate the ship and her machinery. Ship's personnel who are on board to observe the trial should carefully inspect

the operation and material condition of machinery and equipment. Any defects or deficiencies should be noted and brought to the attention of division or engineer officer, so that the items can be discussed with the appropriate members of the Board of Inspection and Survey.

Survey of Ships

Survey of a ship is conducted by the Board of Inspection and Survey whenever a ship is deemed by CNO to be unfit for further service, because of material condition or obsolescence. The Board will, after a thorough inspection, render an opinion to the Secretary of the Navy as to whether the ship is fit for further naval service, or can be made so without excessive cost.

If the board believes that the ship is unfit for further naval service, the Board will make appropriate recommendations as to the ship's disposition.

TRIALS

Trials are conducted of naval vessels to ascertain the capabilities and efficiency of the machinery installation in compliance with specifications for new ships prior to their preliminary and final acceptance. Trials are also held from time to time to determine the machinery efficiency under service conditions, the extent of repairs necessary, the sufficiency of repairs, and the most economical rate of performance under various conditions of service. The several types of trials that are carried out under specified conditions include (1) builders, (2) preliminary acceptance, (3) final acceptance, (4) post repair, (5) laying up or preoverhaul, (6) recommissioning, (7) standardization, (8) tactical, (9) full power, and (10) economy trials. Post repair, full power, and economy trials are routine ship trials. The full power and economy trials discussed in this chapter are considered as competitive trials or exercises. Information concerning the other types of trials is contained in chapter 9080 of the Bureau of Ships Technical Manual.

FULL POWER AND ECONOMY TRIALS

Type commanders schedule full power and economy trials for all active ships to determine their engineering readiness. They should be conducted especially when ships are traveling from point to point so that as many as possible of a group or unit can be tested under the same conditions.

Ships are expected to be able to conduct prescribed trials at any given time, except when authorized to disable or partially disable. Normally ships are allowed approximately two weeks after tender overhaul and one month after shipyard overhaul for final checks, tests, and adjustments of machinery before being called on to conduct a competitive trial.

Observing Party

The observing party for a full power trial is appointed from another ship when practicable. When a ship is scheduled to conduct a trial when proceeding independently between ports, or under conditions that are considered impracticable to provide observers from another ship, the ship under trial may be directed to appoint the observers. The observers for economy trials may be appointed from the ship under trial. The observing party for engineering trials should consist of appropriate officers and leading petty officers.

The chief observer is responsible for organizing, instructing, and stationing the observers. He checks the ship's draft, either at the beginning of the trial or before the ship leaves port, supervises the performance of the engineroom observers, checks the taking of counter readings, renders all decisions under these instructions, and checks and signs the trial report.

The assistant chief observer assists the chief observer as directed, supervises the performance of the fireroom observers, checks the taking of fuel oil soundings and meter readings, observes smoke as required, and completes the data for trial report.

The observers take the fuel soundings, the ship's draft, meter and counter readings, and other data required for the trial report.

The commanding officer of the ship under trial must provide or designate a suitable system of signals so that fuel soundings and the reading of counters and meters can be taken simultaneously. He also furnishes the chief observer with a written statement of the date of the last undocking and of the authorized and actual settings of all main machinery safety devices and the dates they were last tested. The commanding officer also arranges to have the ship's draft, trim, and liquid loading to conform with the trial requirements. In the event a least draft is not specified, the liquid loading should equal at least 75 percent of the full load capacity.

The chief observer determines the draft and trim before and after the trial. He verifies the amount of fuel on board and corrects this

amount to the time of the beginning of the trial. He determines the rpm required for the full power trial at the displacement and injection temperatures prevailing at the start of the trial.

Trial reports are studied by various naval activities. Therefore, the required data must be correct within the limits of accuracy of the shipboard instruments. The observing party should detect any improper performance or departure by the ship's force from the trial instructions, Bureau of Ship's Technical Manual, or sound engineering practice, and report these deviations to the chief observer immediately. The chief observer verifies these reports and then informs the commanding officer of the ship. He also includes a detailed account of the violations in his trial report to the type commander.

Trial Requirements

Prior to a full power trial, inspections and tests of machinery and equipment should be made to ensure that no material item will interfere with the successful operation of the ship at full power. The extent of the inspections and tests will largely depend on the recent performance of the ship at high speeds, the material condition of the ship, and the time limits imposed by operation commitments.

The engineer officer should report to the commanding officer, not later than one day before the trial, the condition of the machinery installation. He should report whether or not it is in proper condition to proceed with the trial, or if any part, in his opinion, is not in a safe and proper condition.

The trial requirements for each ship, which specify the rpm required for full power at various displacements and injection temperatures, are recommended by the Bureau of Ships to the Chief of Naval Operations who in turn furnishes the approved requirements to the commanders and units concerned. The rpm at 15, 20, and 25 knots are also furnished for ships having a full power speed of 25 knots or greater.

Full power trials are for a duration of four hours as far as the required report data is concerned. The usual procedure is to operate the ship at full power for a sufficient length of time until all readings are constant before starting the official four-hour trial period. The smoke prevention trial (except diesel-driven ships) is held during the last hour of the full power trial and should be run at the same rpm. Economy trials are for a duration of six hours. Different speeds are prescribed for successive economy trials throughout the training cycle.

When trials are scheduled, they should be completed on the specified dates unless they must be interrupted by compelling circumstances. The circumstances include weather conditions that are likely to cause damage to the ship, and material trouble that is likely to cause damage to the ship's machinery or endanger human life.

If a trial performance is unsatisfactory, the ship must hold a retrial to the extent considered appropriate by the type commander to demonstrate satisfactory engineering readiness. The fact that a ship failed to make the required rpm for any hour during the trial and the amount by which it failed are noted in the trial report. Similarly, the kind of smoke and the number of seconds that smoke is observed during the smoke prevention trial is also noted in the report.

Conduct of Trial

Unless otherwise ordered, a full power trial may be started at any time on the date set, provided sufficient time remains so that the smoke prevention run if required, can be held during daylight. The trial is divided into hourly intervals. Readings should be taken at frequent intervals (every 15 minutes) during the hour, and the average reading entered in the hourly column. The fuel expenditures for each division of the trial are determined by the most accurate means available—normally by meter readings corrected for meter error and verified by soundings.

During the smoke prevention run, an observing officer continuously notes the gases emitted from the smoke stacks. He records the kind of smoke and the period in seconds during which any smoke issues from any stack.

Material condition ZEBRA should be set and maintained in the engineering machinery spaces throughout the full power and smoke prevention trials. The machinery plants in modern combatant ships are operated in complete split plant setup and those of other ships in the setup that is the most effective approximation to a split plant that the installation will permit. Access and escape routes are provided for observers and personnel supervisors, as necessary.

Material condition YOKE should be set and maintained in all engineering machinery spaces throughout the economy trials. The conduct of

economy trials should not impose unnecessary restrictions on the activities of other departments.

During all trials, the usual housekeeping and auxiliary loads are maintained, and the minimum services provided should include normal operation of the distilling plant, air compressor, laundry, galley, ventilation systems, elevators (if installed), and generators for light and power under load conditions similar to those required for normal operations at similar speeds under the prescribed material condition.

When conducting a full power trial, many commanding officers usually bring the ship up to a speed of one or more knots below the prescribed trial run speed of the ship. The control of the speed of the ship is then turned over to the engineer officer (except in an emergency). The control engineroom, under the supervision of the engineer officer, will bring the speed up slowly (depending on the conditions of the plant) until the specified speed has been reached.

It is a good policy to check the boiler steaming conditions before ringing up additional turns because for most ships the designed boiler horsepower establishes the maximum speed that a ship can attain. The boilers should not be loaded down faster than they are capable of taking care of the increased load. The steam pressure and temperature should be kept at full value for the appropriate steaming condition. The boilers should be the controlling factor and should be kept ahead of the turbines. If the turbines are allowed to get ahead of the boilers, the main steam pressure and temperature will drop below the normal value for that particular steaming condition or speed of the ship. Then, to make up this loss in steam pressure and temperature, and to meet additional increases of speed that may be rung up, the boilers must be fired at an extremely high rate. In some ships this firing rate may exceed the full load rating of the boiler and approach the maximum 120 percent overload capacity rating of the boiler. The primary purpose of the acceleration curve, or table, as far as the engineering department is concerned, is to prevent overloading of the boilers. The use of the acceleration curve is of particular importance when accelerating near full speed and full power.

All ships fitted with indicators, torsion meters, or other devices for measuring shaft or other designated horsepower should take at least two observations during the full power trial to determine the power developed. The chief observer states in his trial report whether all provisions of these instructions have been complied with, particularly as to the ability of the ship to operate satisfactorily under battle conditions.

The critique of the full power and economy trials is held on board the ship under trial as soon as practicable after completion of the trials. It is attended by all of the ship's engineering officers; leading petty officers; and the chief, assistant chief, and departmental observers. The chief observer discusses the overall performance of the trials and comments on any discrepancies or deviations from the trial instructions.

After the critique the chief observer prepares the trial report that is submitted via the chain of command to the type commander. Copies of all satisfactory trials conducted during the first two years of service and of all unsatisfactory trials must be sent to the Chief of the Bureau of Ships.

The purpose of a trial report is to provide a procedure for furnishing the Chief of Naval Operations with early information concerning significant casualties within the naval establishment. There is urgent and continuing need for full knowledge of the material readiness status of fleet units to meet unforeseen emergencies, and timely data on the number and nature of casualties of fleet units to facilitate broad maintenance planning. Initial reports, even though incomplete, must be made without delay, followed by appropriate supplementary reports.

Each copy of the trial report consists of one copy of the Engineering Trial Report Transmittal Letter, OpNav form 3540-3A; one set of the Engineering Trial Report Trial Data OpNav form 3540-3B, sheets 1, 2, and 3 for steam-driven ships and OpNav form 3540-3C, sheets 1 and 2 for diesel-driven ships and submarines; and one copy of the written statement furnished to the chief observer by the commanding officer of the ship under trial. As previously mentioned, this statement contains the date of the last undocking, the authorized and actual settings of all main machinery safety devices, and the dates when these devices were last tested.

CHAPTER 9

SAFETY PRECAUTIONS

Responsibility for the safety of personnel is vested in the commanding officer. Article 0712 of U. S. Navy Regulations reads as follows: "The Commanding Officer shall require that all persons concerned are instructed and drilled in applicable safety precautions and procedures; that they are complied with and that applicable safety precautions or extracts therefrom are posted in appropriate places. In any instance where safety precautions have not been issued or are incomplete he shall issue or augment such safety precautions as he deems necessary, notifying when appropriate, higher authorities concerned."

While the commanding officer cannot delegate his responsibility for the safety of all personnel under his jurisdiction he must necessarily delegate his authority to all officers and petty officers under his command to ensure that all prescribed safety precautions are understood and enforced according to the above article.

As the leading Electrician's Mate your responsibilities regarding safety may be grouped into three areas as follows:

1. Responsibilities concerning the EM group or E division—these responsibilities include ensuring that all men in the group are aware of and are observing all shipboard safety precautions, especially those regarding electrical safety.

2. Responsibilities concerning non-electrical ratings—as an EM1 or Chief Electrician's Mate you will automatically be considered an expert on electrical safety precautions. Thus you have a responsibility to educate the men, whose primary duties are non-electrical, in these precautions. The responsibilities in this area are ever increasing as more and more electrical machines and equipment are being utilized for the various jobs aboard ship.

3. Responsibilities as a petty officer—in this area you have the same responsibilities as all other petty officers of equal rates in enforcing all safety precautions.

ELECTRIC SHOCK

From 1946 through 1962, 98 men died as a result of electric shocks received aboard U. S. Navy ships (fig. 9-1). Table 9-1 summarizes each death from 1957 through 1962 as to rate, type of ship, voltage, and equipment involved.

Current flow through the body is the cause of electric shock. Factors determining the extent of the body damage due to electric shock are the amount and duration of the current flow, the parts of the body involved, and the frequency of the current if a-c. In general, the greater the current or the longer the current flows, the greater will be the body damage. Body damage is also greatest when the current flow is through or near nerve centers and vital organs. Sixty-cycle current is considered slightly more dangerous than current of a lower frequency or d-c. This difference is small, however, and the same precautions that apply to 60-cycle a-c also apply to d-c.

Men differ in their resistance to electric shock, and consequently a current flow that may cause only a painful shock to one man might be fatal to another. Table 9-2 presents information from authoritative sources on the effects of 60-cycle currents flowing through the body from hand to hand or hand to foot. BuShips Technical Manual summarizes the effects of 60-cycle currents with 3 brief statements as follows:

1. At about 1 ma (.001 ampere) shock is perceptible.

2. At about 10 ma (.010 ampere) shock is sufficient to prevent voluntary control of the muscles.

3. At about 100 ma (.1 ampere) shock is fatal if it lasts for 1 second or more.

High frequency currents ranging from about 200 kc and above have a tendency to flow along the surface of the skin (skin effect) and persons coming into contact with these currents usually

Table 9-1.—Summary of Shipboard Deaths Due to Electric Shock—1957 through 1962.

Death No.	Rate	Type Ship	Voltage	Equipment
		1957		
1	FTC	DE	800 a-c	Radar
2	BT3	EDE	120 a-c	Portable light
3	SN	DE	120 a-c	Portable grinder
4	FN	CVA	120 a-c	Portable light
5	FT1	DDR	800 a-c	Radar
6	EMC	DDE	440 a-c	Motor (vent set)
7	SA	AO	120 a-c	Portable wire brush
8	SN	CVS	440 a-c	Portable welder
9	SN	AR	120 a-c	Fan
10	TM3	AR	120 a-c	Gooseneck lamp
11	BTFA	CVS	120 a-c	Portable light
12	EM3	AKA	230 d-c	Power panel
		1958		
1	FA	DDR	440 a-c	Controller panel
2	FN	DD	120 a-c	Portable light
3	EM1	SSK	120 d-c	Light in generator
4	MM3	DD	120 a-c	Electric drill
5	EM3	LST	446 a-c	Main switchboard
6	EM3	ARS	120 d-c	Electric drill
7	FN	DD	120 a-c	Lighting fixture
		1959		
1	SOG3	DDE	8000 a-c	Sonar transmitter
2	SOSN	DDE	8000 a-c	Sonar transmitter
3	AN	CVA	120 a-c	Portable wire brush
4	ET3	CVA	2000 d-c	Radio transmitter
5	EM3	CVA	440 a-c	Controller cover
6	FA	CVS	440 a-c	Open electrical box
7	RM3	SS	120 a-c	Radio cabinet
8	SFM3	DD	50 d-c	Welding electrode
		1960		
1	MM3	DDE	120 a-c	Electric drill
2	ETR SN	AGC	9600 d-c	Radar
3	ICFN	APA	120 a-c	I.C test panel
4	SF3	DD	50 d-c	Welding electrode
5	EMFN	DDR	440 a-c	Controller panel

Table 9-1.—Summary of Shipboard Deaths Due to Electric Shock—1957 through 1962—Continued.

1961

Death No.	Rate	Type Ship	Voltage	Equipment
1	FN	AFDM	440 a-c	Vent motor
2	SOG3	DD	8000 d-c	Sonar transmitter
3	EM3	CVA	450V a-c	Gen. dis. switch
4	SOG3	DDR	5400 d-c	Sonar equipment
5	SD2	CA	440 a-c	Fry kettle
6	FA	AV	450 a-c	Main switchboard
7	SOG3	DDE	5400 d-c	Sonar
8	EM3	DD	440 a-c	Control panel fire and flushing pump
9	FN	DDR	120 a-c	Extension cord
10	EM3	DDR	120 a-c	Flexible cable

1962

1	YN1	T-AP	115 a-c	Guitar amplifier
2	EM3	DD	440 a-c	Galley range
3	RM/SN	AGS	2500 d-c	AN/SQS-30 sonar
4	EM/FN	DDE	440 a-c	Casualty pwr terminal
5	SOG3	DD	5400 d-c	AN/SQS-30 sonar
6	BM2	AR	450 a-c	Ventilating set

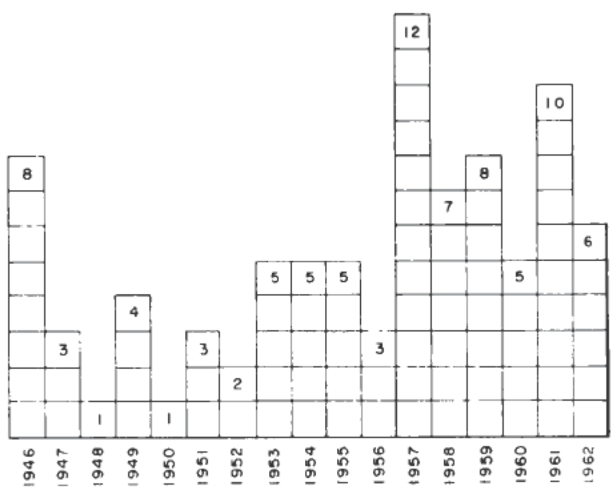

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Figure 9-1.—Deaths caused by electric shock on U.S. Navy ships.

suffer severe burns although the current may not penetrate the body.

Two conditions must be present for an electric current to flow through the body and cause electric shock.

1. The body or some part of the body must form part of a closed circuit.

2. Somewhere in the closed circuit there must be a voltage, or a difference in potential, to cause a current flow. It follows then, to prevent electric shock you should, if possible, ensure that your body never forms part of a closed circuit.

Tests made by the National Bureau of Standards show that the resistence of the human body may be as low as 300 ohms under unfavorable conditions such as those caused by salt water and perspiration. This indicates immediately that it is possible for a potential difference as low as 30 volts to cause the fatal .1 ampere current flow through the body. It is

Table 9-2.—Sixty-Cycle Current Values Affecting Human Beings.

Current Value	Effects
Less than 1 ma	No sensation.
1 to 20 ma	Mild sensation to painful shock, may lose control of adjacent muscles between 10 and 20 ma.
20 to 50 ma	Painful shock, severe muscular contractions, breathing difficult.
50 to 200 ma	Same as above, only more severe, up to 100 ma. A heart condition known as ventricular fibrillation may occur anywhere between 100 and 200 ma causing death almost immediately.
Over 200 ma	Severe burns and muscular contractions so severe that the chest muscles clamp the heart and stop it for the duration of the shock.

true that this would be an extremely unfavorable condition; however, it leaves no doubt as to the dangers involved and precautions necessary regarding the 120-volt circuits aboard ship.

Practically all electric shocks are due to human failure, rather than equipment failure. Equipment may suddenly fail and cause fatal shock even if skillfully designed for safety, thoroughly tested before use, and used in accordance with applicable safety precautions. This can happen, but rarely does. Nearly all of the shipboard deaths reported in figure 9-1 were caused by human failure manifested in one or more of the following ways:

1. Unauthorized use of, or unauthorized modifications to equipment.
2. Failure to observe the applicable safety precautions when using equipment or when working on or near energized equipment.
3. Failure to repair equipment which was known to be defective and had previously given a mild shock to users.
4. Failure to test and inspect equipment for defects or failure to remedy all defects found by tests and inspections. All of these failures may be summarized as failure to observe applicable safety precautions.

ELECTRICAL SAFETY PRECAUTIONS

Preventing injury or death due to electric shock, and damage to electrical equipment, requires strict adherence to applicable electrical safety precautions by all personnel concerned.

In addition to the general electrical safety precautions as discussed in Electrician's Mate 3 & 2, NavPers 10188-B, and The Bureau of Ships Technical Manual, there are other special precautions that apply to specific electrical equipments, and to certain types of electrical jobs. As an EM1 or Chief Electrician's Mate you must be thoroughly familiar with these precautions as applied to the equipment and electrical work on your ship.

Discussed below are electrical safety precautions relating to portable electrical equipments such as drills, grinders, wire brushes, buffers, and test equipment, and precautions and procedures concerning special electrical jobs such as servicing switchboards, removing meters and instrument transformers, and connecting and disconnecting shore power.

PORTABLE ELECTRICAL EQUIPMENT

For protection against electric shock, Navy specifications for all portable electrical equipment such as drills, grinders, wire brushes, sanders, buffers, etc., require the electric cord for the tool to be provided with a distinctively marked grounding conductor in addition to the conductors supplying power to the tool. Past practice was to use red for the grounding conductor in 3-conductor cords and green in 4-conductor cords. Revised specifications require that green be used for the grounding conductor in all cords for portable electrical equipment. BuShips has standardized on the use of grounded type plugs and receptacles to be installed on all ships. The use of a grounding conductor separate from the power cord and grounding to the ship with alligator clamps is considered generally unsatisfactory.

A separate ground wire must be used, however, if the plug and receptacle are not the grounding type. Alligator clamps are considered

generally unsatisfactory because a man may forget to use them, or he may not use them properly. He may fail to connect the ground wire first before connecting the equipment to the power receptacle, or he may erroneously disconnect the ground wire first before unplugging the equipment. Also the alligator clamp may slip off the surface to which it is attached, or it may not make a good ground connection due to paint, corrosion, or other insulating films.

All portable electrical equipment before being used for the first time must be tested, and periodic tests and inspections made thereafter on the equipment and installed receptacles according to the Bureau of Ships Technical Manual, chapter 9600.

Personal portable electrical equipment such as radios, record players, TV sets, and coffee pots must be tested to insure that they meet Navy specifications before being allowed on board ship. If they do meet specifications and are allowed on board, they require the same periodic tests and inspections as other portable electrical equipment.

TEST EQUIPMENT

The electrical measuring instruments included in portable test equipment are of delicate construction, therefore certain precautions are necessary to avoid damage to the instruments and to ensure accurate readings. In addition there are other precautions that must be observed while using portable test equipment to avoid electric shock.

Precautions that apply to all electric measuring instruments to avoid damage are:

1. Avoid mechanical shock—although the moving elements in electrical measuring instruments are light in weight the bearing pressure at pivots and jewel bearings often exceeds 10 tons per square inch because of the small area of the bearing surface.

2. Avoid exposure to strong magnetic fields—strong magnetic fields may permanently impair the accuracy of an instrument by leaving permanent magnetic effects in the magnet of permanent magnet moving coil instruments, in the iron instruments, or in the magnetic materials used to shield instruments.

3. Avoid excessive current flow—this includes various precautions depending on the type of instrument. Make connections while the circuit is deenergized if possible, and then check all connections to ensure that no instrument is overloaded before energizing.

4. Ensure that meters in motor circuits can handle the motor starting current which may be as high as 7 or 8 times normal running current.

5. Never leave an instrument connected with its pointer off scale or deflected in the wrong direction.

6. Never attempt to measure the internal resistance of a meter movement with an ohmmeter as the movement may be damaged by the current required to operate the ohmmeter.

Some of the dangers to personnel when using test equipment are coming into contact with live terminals or test leads, instruments being accidentally thrown to the deck due to a sudden roll of the ship; and personnel becoming entangled with the leads or cords. In addition, if two or more test instruments are being used, the situation may be such that a potential difference sufficient to cause severe shock may exist between the metal cases of the instruments.

Wires attached to portable test equipment should extend from the back of the instruments away from the observer if possible. If this is not possible, they should be clamped to the bench or table near the instruments. When using instruments at places where vibration is present the instruments should be placed on pads of folded cloth, felt, or similar material. Additional precautions are necessary when using portable test equipment during heavy seas.

Precautions to be observed to avoid injury to personnel include the following:

1. Ensure that the metal cases of all instruments are grounded.

2. Ensure that one side of the secondary of every external instrument transformer is also grounded.

3. If equipment must be energized for testing after removal from its normal rack or mounting, ensure that all parts normally at ground potential are securely grounded.

4. Avoid testing voltages in excess of 300 volts when holding test probes in the bare hands. Use rubber gloves or attach test leads after the equipment has been deenergized, then energize the equipment and read the meter. Ensure that any high voltage capacitors in the circuit and the terminals to be tested are discharged before attaching or disconnecting the test leads.

5. When feasible check for continuity and resistance rather than directly checking voltages.

6. Keep all unauthorized personnel clear of the area where portable test equipment is being used.

SERVICING SWITCHBOARDS

Switches should be operated with both the safety of the operator and other personnel in mind. Before closing any switch be sure the circuit is ready in all respects to be energized and any men working on the circuit are notified that it is to be energized.

When operating circuit breakers or switches use only one hand if possible. Use judgment in replacing blown fuses. Only fuses of 10 ampere capacity or less should be removed or replaced in energized circuits. Fuses larger than 10 ampere ratings should be removed or replaced only when the circuit is deenergized. Work should not be done on any energized circuit, switchboard, or other piece of electrical equipment unless absolutely necessary. Circuits or equipment to be worked on should be deenergized by opening all switches through which power could be supplied and the circuit then tested with a voltmeter or voltage tester. These switches should then be tagged with warning tags. In case more than one party is engaged in repair work on a circuit a warning tag for each party should be placed on the supply switches.

When checking to see whether circuits are deenergized before starting repair work on switchboards be sure to check metering and control circuits.

Some instrument transformers will be energized even though main circuit breakers are open.

When military considerations require that electrical repair work be done on energized switchboards permission to do the work must be obtained from the commanding officer. The work should be done only by adequately supervised personnel fully cognizant of the dangers involved, and the following precautions observed.

1. Provide ample illumination.

2. The person doing the work should not wear wristwatch, rings, watch chain, metal articles, or loose clothing which might make accidental contact with live parts or which might accidentally catch and throw some part of his body into contact with live parts. Clothing and shoes should be as dry as possible.

3. Insulate the worker from ground by means of insulating material covering any adjacent grounded metal with which he might come in contact. Suitable insulating materials are dry wood, rubber mats, dry canvas, dry phenolic material, or even heavy dry paper in several thicknesses. Be sure that any such insulating material is dry, has no holes in it, and no conducting materials embedded in it. Cover sufficient areas so that adequate latitude is permitted for movement by the worker in doing the work.

4. Cover working metal tools with insulating rubber tape (not friction tape) as far as practicable.

5. Insofar as practicable, provide insulating barriers between the work and any live metal parts immediately adjacent to the work to be done.

6. Use only one hand in accomplishing the work, if practicable.

7. A rubber glove should be worn on the hand not used for handling the insulated tools. If the work being done permits, rubber gloves should be worn on both hands.

8. Station men by circuit breakers or switches, and man a telephone if necessary, so that the circuit or switchboard can be deenergized immediately in case of emergency.

9. A man qualified in first aid for electric shock should be immediately available while the work is being done.

These precautions apply to repair work on all energized circuits or equipment where the voltage exceeds 30 volts.

REMOVING METERS AND INSTRUMENT TRANSFORMERS

When removing or installing switchboard and control panel meters and instrument transformers, care must be exercised to avoid electric shock to yourself, and damage to the transformers and meters.

Keep in mind that some potential transformer primaries may be energized even though all power circuit breakers are off. In most installations potential transformer primaries are fused, and the transformer and associated meter can be removed after pulling the fuses for the transformer concerned. Care must be exercised in disconnecting the transformer and meter leads however to avoid contact with nearby energized leads and terminals.

If the transformer primary is not fused, all supplies to the switchboard or panel concerned must be deenergized and tagged at the source before disconnecting the transformer.

To prevent damage to instrument transformers, never open the secondary of a current transformer while the primary is carrying current, and never short circuit the secondary of a potential transformer while the primary is energized.

To prevent damage to the meters, observe the precautions listed previously for portable test equipment.

CONNECTING AND DISCONNECTING SHORE POWER

Due to the hazards involved, connecting and disconnecting shore power should be supervised by the senior or leading Electrician's Mate. The procedures for connecting and disconnecting shore power and precautions to be observed will vary slightly depending upon the type of ship concerned. The procedures applicable to most ships are listed below.

Connecting

1. Before connecting the shore power cable, with the shore power circuit breaker off and tagged, test the terminals in the ship's shore power terminal box with a voltage tester to ensure that they are deenergized. Then test the insulation resistance between terminals and to ground with a megger. The fuses for shore power voltmeter and/or indicating light transformer primaries must be pulled to get an accurate insulation resistance reading between the shore power terminals.
2. Connect one end of the shore power cable to the terminals in the ship's shore power terminal box according to the phase or polarity markings in the box and on the cable.
3. Check the terminals in the source shore power terminal box to ensure that they are deenergized, then connect the other end of the shore power cable to these terminals, observing polarity or phase markings as before.
4. At the ship's shore power terminal box, connect the phase sequence meter (if three phase a-c) to the proper terminals, then energize the cable from the shore power source.
5. Check for proper phase sequence by observing the phase sequence meter. If the phase sequence is correct, deenergize the cable, disconnect the phase sequence meter, and reenergize the cable.
6. If the phase sequence is incorrect, deenergize the cable, recheck the phase sequence meter connections, and if they are correct, interchange any two of the shore power cable conductors.
7. Energize the cable from the shore power source, ensure that the phase sequence is correct, deenergize the cable, disconnect the phase sequence meter, and reenergize the cable.

The above procedure is modified slightly for d-c ships as the shore power polarity may be checked with a polarity indicating voltage tester. The procedure also differs slightly for the plug-in type of shore power cable presently being installed on new ships. The phase sequence check for the plug-in type of shore power cable must be made before the cable is plugged into the ship's shore power box. The phase sequence meter is connected to the three male prongs of the plug on the end of the shore power cable while the cable is deenergized. The cable is also deenergized to remove the phase sequence meter connections as before. Care must be exercised in making the phase sequence check to avoid shorting the male prongs of the plug.

Disconnecting

To disconnect the shore power cable, proceed as follows:

1. After the electrical load has been shifted to the ship's generators, with the ship's shore power circuit breaker off and tagged, ensure that the supply circuit breaker at the shore power source is off and tagged.
2. At the source shore power terminal box, test the terminals to ensure that they are deenergized, and disconnect the cable.
3. At the ship's shore power terminal box, test the terminals to ensure that they are deenergized and disconnect the cable. If the cable is the plug-in type, unplug the cable, then test the male prongs of the plug to ensure that the cable is deenergized before unrigging the cable.

Supervising

Connecting and disconnecting shore power requires close on-the-job supervision. In some cases, the connecting and disconnecting at the shore power source will be done by personnel attached to the activity furnishing the shore

power. This means that both ends of the shore power cable may be in the process of being connected or disconnected simultaneously by separate groups under separate supervisors. This requires the special attention of both supervisors in coordinating the work of the two groups.

As the supervisor attached to the ship receiving shore power, you are responsible for ensuring that the prescribed procedures for your particular ship are carried out. You are responsible for informing (in person) the supervisor attached to the activity furnishing shore power, when to energize or deenergize the shore power cable. You should also inform him, if possible, before opening your shore power circuit breaker while receiving shore power.

As the supervisor attached to the activity furnishing shore power, you are responsible for ensuring that the prescribed procedures for your activity are carried out. You are also responsible for ensuring that the shore power cable is energized only upon direct word from the supervisor or other appropriate authority attached to the ship receiving shore power. You should also inform the supervisor of the ship receiving shore power, if possible, before opening the shore power supply circuit breaker while supplying shore power.

SAFETY PRECAUTIONS WHEN USING SOLVENTS AND VOLATILE LIQUIDS

Some solvents are flammable, others are toxic, and still others are both flammable and toxic. Alcohol must not be used on energized equipment or near any energized equipment from which a spark may be received. Gasoline or benzine should not be used for cleaning purposes under any circumstances. Carbon tetrachloride is not to be used because of its extremely high toxicity. Inhibited methyl chloroform or trichloroethane are approved cleaning solvents for applications in which carbon tetrachloride was previously used. Although these solvents are less toxic than carbon tetrachloride, they do present hazards to personnel, hence the following precautions must be observed when they are used.

1. Use with adequate ventilation.
2. Avoid prolonged breathing of the vapor.
3. Avoid prolonged or repeated contact with the skin.
4. Do not take internally.

These same precautions also apply when working with volatile liquids such as insulating varnish, lacquer, turpentine, and paints.

Solvent, dry cleaning, type 2 is also an approved solvent in which the fire and health hazards have been minimized. Precautions against fire and explosion should still be observed, however, when using this solvent.

SAFETY REQUIREMENTS IN WORK AREAS

Safety requirements concerning the various shops and work areas aboard ship are prescribed by the BuShips Technical Manual, and other authority. The requirements for electrical or electronic working areas include the following:

1. Rubber matting meeting military specifications is to be provided in the front and rear of all power and lighting, action cut out, I.C., and F.C. switchboards. This matting is also required in front of shipboard announcing system amplifiers and control racks, on areas around electronics equipment which may be contacted by personnel in servicing or tuning, and on areas in front of test benches or tables in electrical and electronic shops. Latest instructions require such matting to be cemented to the deck except on gratings and removable deck plates.
2. "Danger-high Voltage" signs and suitable guards are to be provided to warn all personnel, wherever live circuits or equipment are exposed when the voltage exceeds 30 volts.
3. All rear service switchboards are required to have an expanded metal enclosure with a door. This enclosure is not to be used as a storage space and the door must remain locked.
4. First aid treatment for electric shock and other applicable electrical safety precautions are to be posted in all areas containing major units of electrical or electronic equipments.
5. "No Smoking" signs are to be posted in spaces where storage batteries are charged, and all other spaces where explosive vapors may be present.

SAFETY DUTIES AND RESPONSIBILITIES

Your responsibilities concerning safety lie in three areas as mentioned previously. The duties required to meet these responsibilities will include safety education, safety promotion, and safety enforcing duties.

SAFETY EDUCATION

You cannot expect a man to observe a precaution if he is unaware of the precaution. Your first duties therefore will be to ensure that all men in the EM group are aware of the safety precautions applicable to your ship. Ships such as AO's and AE's necessarily have some precautions that may not apply to other type ships. Ensure that all men have read and understand all posted safety precautions relating to the ship's electrical equipment.

Safety education for the non-electrical ratings should include information concerning electric shock and precautions they must observe when using electrical equipment aboard ship.

Facts to be brought out and points to stress to the non-electrical ratings concerning electric shock should include the following:

1. Voltages as low as 30 volts can be dangerous.
2. The dangers from electric shock are much greater aboard ship than ashore as the ship can be considered a floating bathtub.
3. There is very little middle ground between a slight tingle and a fatal shock.

Precautions they must observe when using electrical equipment include the following:

1. Always visually inspect portable electrical equipment before using. Look for damaged plugs, frayed cords, etc.
2. Never use portable electrical equipment if it is believed to be defective. Have it tested by authorized personnel.
3. Make no repairs.
4. Do not use any personal portable electrical equipment aboard ship unless it has been inspected and approved.
5. Always report any shock received from electrical equipment, regardless of how slight.

PROMOTING SAFETY

Promoting safety within the EM group, E division, or the ship in general will require you to become safety conscious to the point that you automatically consider safety in every job or operation. By safety reminders and your personal example you pass this safety consciousness on to the other men.

All men, even the "old hands" need to be reminded occasionally to work safely. The senior electrical rates involved in the fatal accidents (table 1) bear out this fact.

Promoting safety within the EM group can be done by various methods. Posters of the type shown in figure 9-2 can be helpful as safety reminders and in promoting safety. These posters are furnished periodically to all ships. Post them in your work areas and change them when new ones are available.

Periodic safety patrols or inspections made by the junior men in the group can also be helpful in promoting safety within the group and in reducing electrical hazards such as storage of foreign articles in or near switchboards, control appliances and panels, open panels or covers missing from junction boxes, etc.

In addition, occasional short group discussions concerning electrical safety are recommended. These discussions may take place at any time without prior preparation. There will be at least one man in the EM group every month or oftener that receives a slight shock. This can be the basis of the discussion. Have the man concerned relate the exact circumstances under which he received the shock. The group then discusses the slightly different conditions that might have prevailed causing the shock to be more severe or perhaps fatal.

The film list in appendix 1 of this training course includes film concerning safety that will be helpful both as safety reminders and for safety education.

ENFORCING SAFETY

Safety precautions as all rules, laws, or regulations must be enforced. It is your duty to take appropriate action any time you see a junior man disregarding a safety precaution. You must require that all jobs be done according to applicable safety precautions.

Doing a job the safe way in some cases may take a little longer or be a little more inconvenient, however, there is no doubt as to the importance of doing it this way.

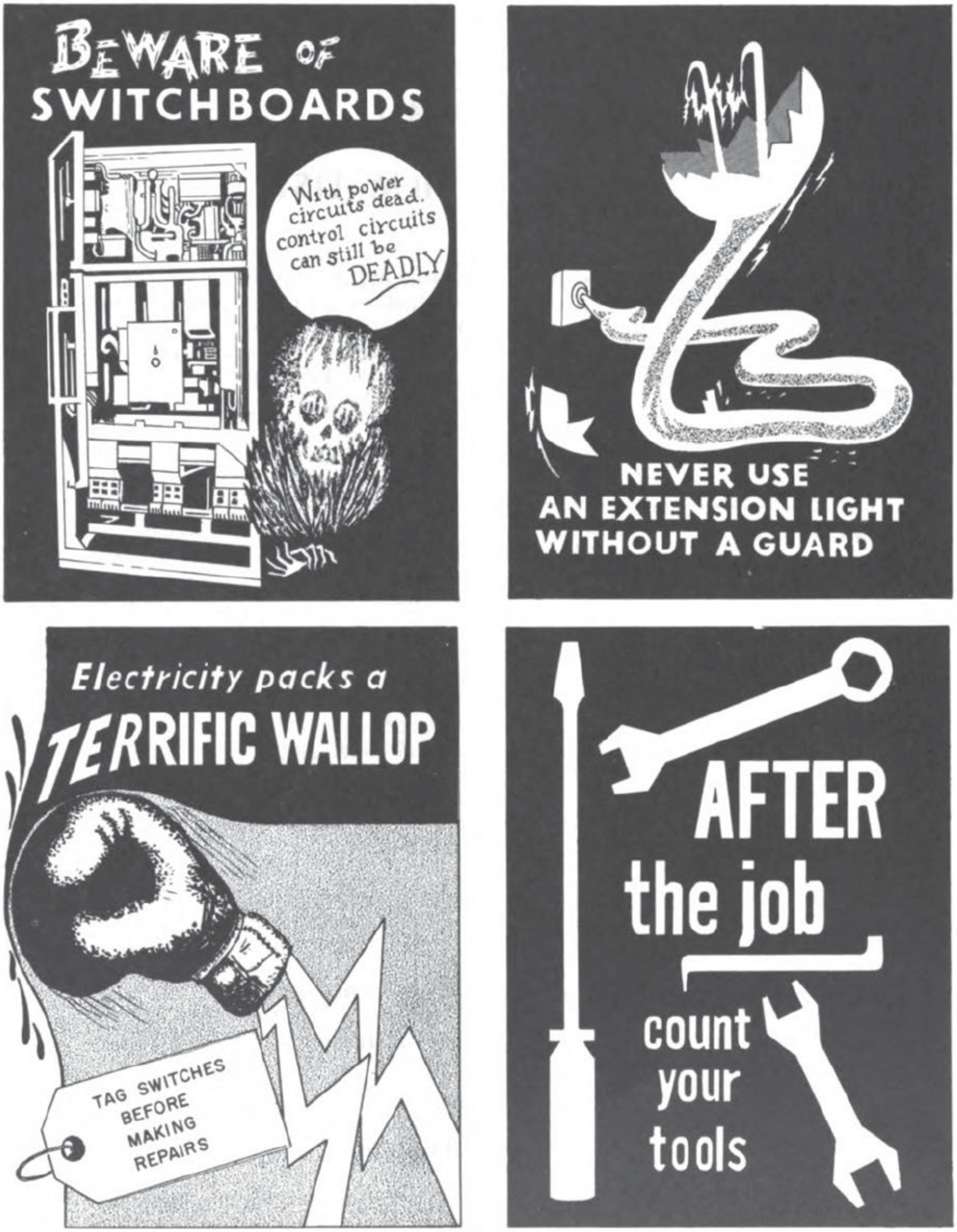

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Figure 9-2.—Sample-electrical safety posters.

APPENDIX I

TRAINING FILM LIST

Training films that are directly related to the information presented in this training course are listed below. Under each chapter number and title the training films are identified by Navy number and title and are briefly described. Other training films that may be of interest are listed in the United States Navy Film Catalog, NavPers 10000 (revised).

Chapter 3

A-C WINDINGS

ME-7373A — Three Phase Motor—Part 1—Preparing to Rewind. (28 min. —B&W—Sound—Unclassified—1946.) USOE OE-395. Shows how to interpret and record nameplate data of a three-phase motor; identify line leads and finish leads; remove coils and determine coil span; use a coil winding machine; and end-tape machine wound coils.

ME-7373B — Three-Phase Motor—Part 2—Rewinding. (17 min. —B&W—Sound—Unclassified—1946.) USOE OE—396. Shows how to insert mush coils; insert separators or "Willies"; fold, trim, and wedge slot insulation around windings; insert phase insulation, and make a delta connection.

SE-7373AA — Three-Phase Motor—Part 1—Preparing to Rewind. (35 frames-B&W-Silent-Unclassified-1946.) USOE OE-395. Accompanying filmstrip for ME-7373A.

SE-7373AB — Three-Phase Motor—Part 2—Rewinding. (31 frames-B&W-Silent-Unclassified-1946.) USOE OE-396. Accompanying filmstrip for ME-7373B.

Chapter 5

AUTOMATIC DEGAUSSING

MN-9679A — EMS Magnetometer Controlled Degaussing Systems, Principles of Operation. (22 min. —B&W—sound—Unclassified—1963.) Shows principles of operation and operating procedures for EMS automatic degaussing control systems.

MN-9679B — EMS Magnetometer Controlled Degaussing Systems, Maintenance and Repair. (15 min.—B&W—sound—Unclassified—1963.) Explains general principles of preventive maintenance and repair of magnetometer controlled degaussing systems.

Chapter 9

SAFETY PRECAUTIONS

MN 8990 — 115 Volts—Deadly Shipmate. (19 min.—color—sound—Unclassified—1960.) This film tells the story of "Joe" who is representative of all sailors, and is based upon the re-enactment of actual cases. It emphasizes the disastrous effects of low voltage shock when the basic rules of electrical safety are violated or ignored.

MN 8639 — Safety On-the-job at Sea. (16 min.—B&W—sound—Unclassified—1957.) This film shows organization for shipboard safety, how shipboard accidents can occur, accident prevention afloat, and emphasizes the importance of crew safety consciousness.

INDEX